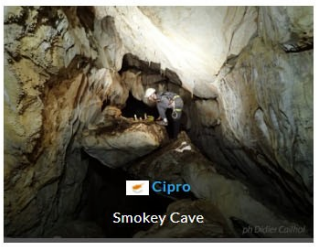
# SPELEOMEDIT

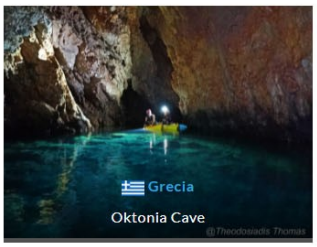
## Mediterranean speleology



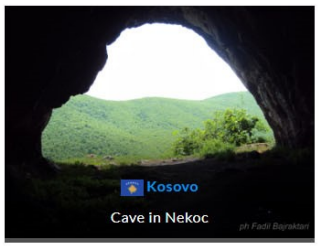







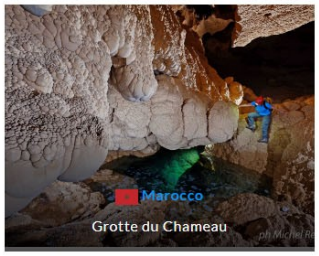





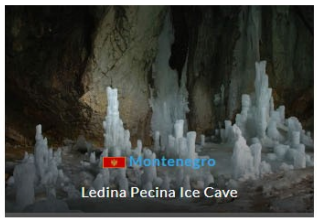

















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SSI SOCIETÀ SPELEOLOGICA ITALIANA

Esplorare, conoscere e proteggere

# SPELEOMEDIT

# *Mediterranean Speleology*

***Panoramic view of caves and karst of Mediterranean countries***

**Editors**

**Ferdinando Didonna and Francesco Maurano**

**Tetide APS - Marina di Camerota**

**Società Speleologica Italiana - Bologna**

**2021**


**International Year of Caves and Karst: IYCK**

**Mediterranean flag**

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**On the cover: Collage of Mediterranean Caves - Graphic Francesco Maurano**

SPELEOMEDIT PROJECT

In December 2019 the Board of the Italian Speleological Society started to plan planning the activities for 2021 International Year of Caves and Karst and for the International Speleo Kamaraton Meeting in Marina di Camerota, a coastal town in the middle of the Mediterranean Sea.

The fundamental idea of the project is to collect and disseminate information on the speleological activities of Mediterranean countries, and promote research and documentation by local speleologists with the aim of offering all the collected data on a shared Web platform.

The project aims to make an important contribution to create a common awareness and strengthen the links between speleological groups and research institutions in the Mediterranean, in order to increase capacity and actions to support karst and caves protection.

We have chosen to propose scientific and geographical information with an info-card file for each country overlooking the Mediterranean, after collecting the information directly in each country from authors of active caving organizations or authors who have done research in these countries.

The path was not easy, we started by contacting the delegates of the International Union of Speleology of the Mediterranean countries, but we went further on by searching for active speleologists from each country, and encouraging them to search for salient information about the caves, karst, and speleology in their countries.

The first result is available on the web page http://www.speleokamaraton.eu/speleomedit/ with a one-page summary info-card for each participating country.

The second result is this publication that hosts an extensive description of caves and karst of Mediterranean countries.

These data are accompanied by 7 general articles that give a panoramic view of karst, geomorphology, hydrology, biogeography and underground biology, anthropogenic cavities, as well as the history and cults linked to the caves in the Mediterranean area.

The third result is a photographic exhibition curated by the Spanish photographer and speleologist Victor Ferrer, with the purpose of showing the beauty of karst environments, fragile caves, and the incredible life that dwells in them to stimulate the protection of the caves of these spectacular environments with 51 different panels pictures from Mediterranean countries.

The data of the volume Mediterranean Speleology and of the exhibition are presented for speleologists but also aimed at the general public, who will be able to discover ~250,000 natural and artificial caves of the Mediterranean countries, and ~9,000 sea caves besides other interesting and useful information.

The SpeleoMedit project has grown in these difficult two years by stimulating the local stakeholders to search and systemize information that is often unavailable or dispersed in specialized publications.

We are thankful to the Società Speleologica Italiana, Europea Speleologica Federatio and Oficina de Cultura de la Embajada de España among other national caving organizations (Federazione Speleologica Campana, Federazione Speleologica Pugliese, Federazione Speleologica Regionale del Friuli Venezia Giulia, Federazione Speleologica Veneta) for their support and contribution and to many friends who have donated to the crowdfunding campaign.

SpeleoMedit has been one of the first action that the Tetide association is carrying out to promote the Mediterranean Speleology and the cave and karst protection, in the framework of www.speleokamaraton.eu international meeting.

We hope that you will enjoy reading this book and that you will continue to support SpeleoMedit in its future projects and updates.

Ferdinando Didonna[1] and Francesco Maurano[2]

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# INTRODUCTION TO SPELEOMEDIT

## MEDITERRANEAN SPELEOLOGY

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Abîme de Bramabiau (Gard - France)
Ph. Philippe Crochet

The Mediterranean Sea is the home of Western Civilization. Several of the world's major cultures grew along its shores over the past several thousand years. In more recent times, modern speleology began and evolved greatly in the coun-tries that share this sea as a common bond. This is not surprising considering that karst occurs prominently in each Mediterranean country.


Grotte de Malaval (Lozère - France)
Ph. Philippe Crohet


*Italodytes stammeri*
Ph. Enrico Lana

Cave beetles, International Cave Animal of the Year 2021

The SpeleoMedit Project is an important and unique study of caves and karst in the countries bordering the Mediterra-nean Sea. It was conceived as part of the celebration of the International Year of Caves and Karst, a global event orga-nized by the International Union of Speleology to teach the world about the many benefits of caves and karst, the challenges they present to humanity, and their vulnerability to harm. The theme of the International Year is "Explore, Understand, Protect," which is celebrated through this book.

*SpeleoMedit* (*Mediterranean Speleology*) compiles the results of over 100 years of exploration by cavers and cave sci-entists. That exploration had led to understanding of one of the world's most important cave and karst regions, which is shared through this book and which will lead to their better protection and sustainable use on which all countries depend.

For those readers who are new to caves and karst, it is important to explain both. "Karst" is a type of landscape formed by water dissolving the bedrock slowly over thousands or millions of years. As water enters cracks in certain types of rocks that dissolve more easily, the cracks are enlarged, allowing them to accept more water, so they enlarge further. The process self-accelerates in this manner until the cracks become large enough for people to enter, at which time we call them "caves."

The water flowing down through the cracks feed into aquifers, natural underground reservoirs of water, and caves serve as the "pipes" for karst aquifers, eventually draining the water back to the surface via springs. Karst springs are the largest in the world, with many large and historically important springs occurring in the Mediterranean region.

To someone who has not explored or studied caves, it may seem that all caves are basically the same. But that is not true and there is great diversity around the Mediterranean. Most caves form in limestone and the world's highest concentration of caves more than 1,000 m deep occur in European limestones. Many of those caves are also exceptionally long.

While caves in halite, rock salt, are rare, they occur in the arid Mediterranean countries, with the world's longest halite cave in Israel. In contrast to these dry caves, long caves formed at sea level in Greece, Mallorca, and along other coastal areas require swimming and scuba to explore and some are among the most beautiful caves on Earth.

Human history is tied closely to the caves of the Mediterranean. The best preserved bones of our hominin ancestors are found in many caves of the region. France and Spain are especially famous for much of the world's oldest and most spectacular art, even spectacular by today's standards.

More recently, Postojna Jama in Slovenia became the world's first show cave, opening to tourists in 1818. About 70 years later, Édouard Alfred Martel opened the era of modern speleology through his exploration of caves in several Mediterranean countries. Following his work, cave exploration and science grew focused in the Mediterranean and European region resulting in the creation of the first Inter-national Congress of Speleology in 1953, a quadrennial event that

is still the world's most important cave and karst conference. The congress led to the creation of the International Union of Speleology, headquartered in Slovenia (then Yugoslavia) in 1965.

Pick a topic in caves and karst, and chances are that the Mediterranean region will appear prominently in your research. Cave size, depth, and splendor, karst and pseudokarst types (karst-like caves and features formed by non-karst processes), earliest and present day major advances in cave archaeology, biology, hydrogeology, and other fields of study are all found around the Mediterranean.

This history and importance of Mediterranean speleology makes SpeleoMedit an excellent book for the International Year of Caves and Karst. I expect you will be fascinated by what you read in the pages ahead, and that you will want to learn more. If you are inspired to explore caves or study then, visit the website of International Union of Speleology (www.uis-speleo.org) to learn how to contact the speleological organizations in your country.

Remember, dark places are frightening until you shine a light, I encourage you to help shine the light of knowledge about the special nature of caves and karst for this International Year and for the many years ahead.

Grotte di Pertosa-Auletta (Campania - Italy)
Ph. Francesco Maurano

# SPELEOLOGY OF THE MEDITERRANEAN

**Gerard Campion[1] ged.campion@talk21.com**
[1]President, European Federation of Speleology

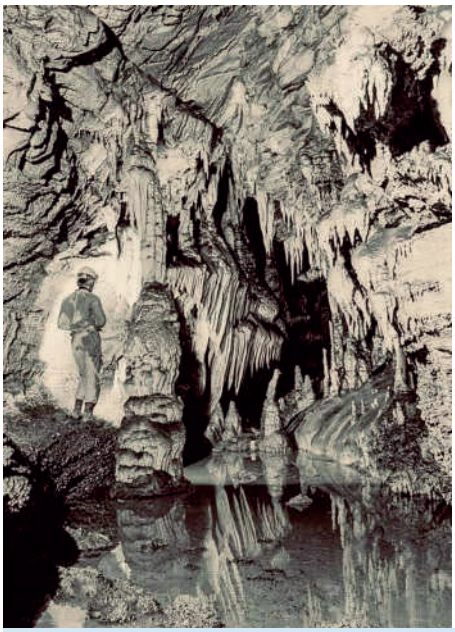
Marine cave Cala Luna Sardinia
Ph. Imogen Campion

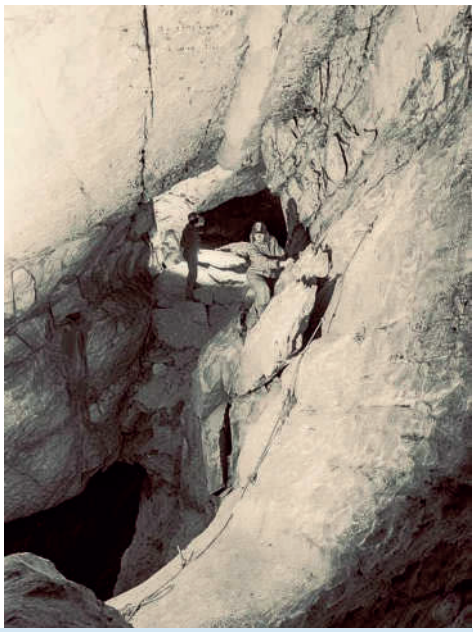
In order to celebrate the International Year of the Caves and Karst (IYCK) the Speleological Society of Italy together with TETIDE have produced this excellent publication that captures the magnificence of the caves and karst that encompass the Mediterranean Sea. How lucky are those to live in Europe to have such an array of diverse landscape, biospeleology and spectacular caving at their fingertips as they gaze over this ancient sea. Exploration and study of this area has been at the forefront of speleology since the science was born. One only has to read Édouard Martel's 'Les Cevennes' to appreciate the crucial meaning of 'Mediterranean' to the Cevennes region. More recently the project 'Phreatic' in the Gulf of Orosei, Sardinia highlights how cave divers have been working hand in hand with scientist to help protect precious environments and make new scientific discoveries at that mysterious interface, where cave waters meet the marine world.

Marine cave Cala Luna Sardinia
Ph. Imogen Campion

Further inland the Mediterranean region has witnessed caving on an epic scale with a rich history of discovery. The Gouffre Berger was the first cave system to surpass the elusive 1,000m depth in 1956. In the Pyrenees mountains cave explorers wrestled with the trauma of losing one of their most promising cave explorers in a tragic accident in Reseau De La Pierre Saint Martin in 1952. In 1983 the Antro Del Corchia was the first Italian cave to reach 1,000 metres. Whether the reader is interested in exploration, archaeology, cave biology, or geomorphology and so on… there is something for everybody in this publication.

It is perhaps no surprise that the concept of this book has received the patronage of the European Federation of Speleology by receiving a well-earned Eurospeleo Projects award. These projects were introduced in 2009 by the European Federation of Speleology to encourage and increase collaboration between European cavers in all aspects of speleology. This project bears testament to how well the concept of collaboration can work between so many diverse nationalities. There are 21 countries that stretch out to the shores of the Mediterranean and in this volume each one has brought their own distinctive character in describing the magnificence of their caves and karst.





Corchia British expedition 1977.
Ph. John Whalley

# MEDITERRANEAN BASIN: OUR COMMON HERITAGE, OUR GEOLOGICAL BOND

**Sergio Orsini[1] presidenza@socissi.it**
[1]President, Società Speleologica Italiana

Grava I del Parchitiello (M. Alburni)
Ph. Francesco Maurano

Thanks to its geographic position and the long shape, Italy is the bridge over the Mediterranean for looking overseas and connecting lands and waters by using karst topics. For this – and more - this work was meant to be born in Italy with the idea to bring back to Italy all the information that the Mediterranean countries are willing to share with the speleological community.

*SpeleoMedit*, born to be the synthesis between speleology, biospeleology, paleontology and hydrology is therefore essential to outline the peculiarities of each country overlooking the Mediterranean and to trace the convergence of many phenomena.

The multiplicity of elements and objective data collected allowed the making of the volume, with its analytical sheets and introductory studies and its many strengths:

- To search for a common denominator among karst phenomena of different countries and emphasize their similarities and differences,
- To collect in an easily accessible tool a heritage that would otherwise be dispersed,
- To give value and promote this heritage,
- To divulge and make known the great speleological potential of the lands bordering the *Mare Nostrum*.

Hence, we can say that this work makes its own and amplifies a project dear to every speleologist, and to the Italian Speleological Society (SSI): to explore underground environment in order to study it, reveal it, protect it, and make its resources appreciated by those who cannot even imagine them. That is why SSI is honored and proud to have sponsored this publication that will enrich our common heritage.

***Mediterranean Speleology*, present and past**

Italy is a territory with vast areas characterized by the presence of various karst rocks that have stimulated modern research and exploration for over a century. But, as we know, human frequentation of caves is ancient: paleontology with its findings abundantly illustrates this fact. In the historical period, it may be interesting to recall the artificial cavities built and exploited by the Romans; particularly noteworthy is the marvel engineering structure that were the underground aqueducts, and in particular I cite, from personal knowledge, having explored its 22 kilometers in length, one of those that are still used today to serve the community: the Roman Aqueduct of Bologna which provide the city and neighboring municipalities with 2400 L/sec of potable water. But not just this: there are countless reservoirs, water reserves, underground water collections such as the famous *Yerebatan Sarnici* in Istanbul, built in the sixth century AD and fed by the Roman aqueduct of Augustus Valens (368 AD).

Then, in closer times, across history and imagination: in his *Divine Comedy*, Dante Alighieri, caver *ante litteram*,

Acquedotto Romano
tratto da “Gli Antichi Acquedotti di Bologna”
Autori vari

Grotta di Frasassi, moonmilk di gesso
Ph. Paolo Forti

explores the subsurface, crosses underground rivers with the same apprehension, curiosity and fear for the unknown of a modern caver. The abbot Serafino Calindri, in 1781 after exploring the territory, describes caves and mines in his *Dizionario corografico, georgico, orittologico, storico […] della Italia*. A century later Jules Verne, with his *Journey to the Center of the Earth*, takes us underground in search of – among other things – remote traces that we still encounter today inside the caves.


Grotta Zinzulusa, *Higginsia ciccaresei*
Ph. Antonio Danieli

We may also bring out the sanctuaries placed inside natural and artificial cavities; the caves chosen as dwellings by anchorites: the caves as quarries for *lapis specularis*, used by the Romans and until the eighth century as glass, and of which we find traces in many basilicas; the caves that were a refuge in times of war. The cultural vestiges that the caves contain are so many that we should stop here and give the floor to this useful and excellent book, which is much more than a book for its interactive value.

In addition, Italy thanks to its variegate geological territory, is the country with the highest abundance of hypogene sulfuric acid caves (almost 25% of the worldwide known sulfuric acid caves are located in Italy). The hypogene sulfuric acid caves are linked with the rising of deep sulfidic and thermal waters and are particularly abundant along the Apennine Chain. One of the most famous hypogene sulfuric acid system is Frasassi, which has been considered a study model all over the world. In Europe facing the Mediterranean Sea these kind of caves have been described in France, Spain, Albania, and of great interest for future exploration is Greece.

In Italy hypogene sulfuric acid caves are located also along the Adriatic and Tyrrhenian coastline, worthy to be mentioned are Capo Palinuro and Santa Cesarea Terme, where recently a great number of scientific and speleological research have been carried out.

We must then say some words about coastal caves, their variety, from Spain to Greece and everywhere else, their spectacular nature but above all their scientific significance. I will mention again data that I personally know: research conducted in the Cocito anchialine system inside the Zinzulusa Cave, in Salento, has led to various discoveries. Here, the cave has become a treasure chest that gradually reveals its secrets kept alive as legacies of past geological eras. An example: the *Higginsia Ciccaresei*, a sponge found a few years ago in the Cocito pool and believed to be extinct since the Messinian period.


Grotta Zinzulusa
Ph. Sergio Orsini

# GEOMORPHOLOGY OF THE MEDITERRANEAN AREA

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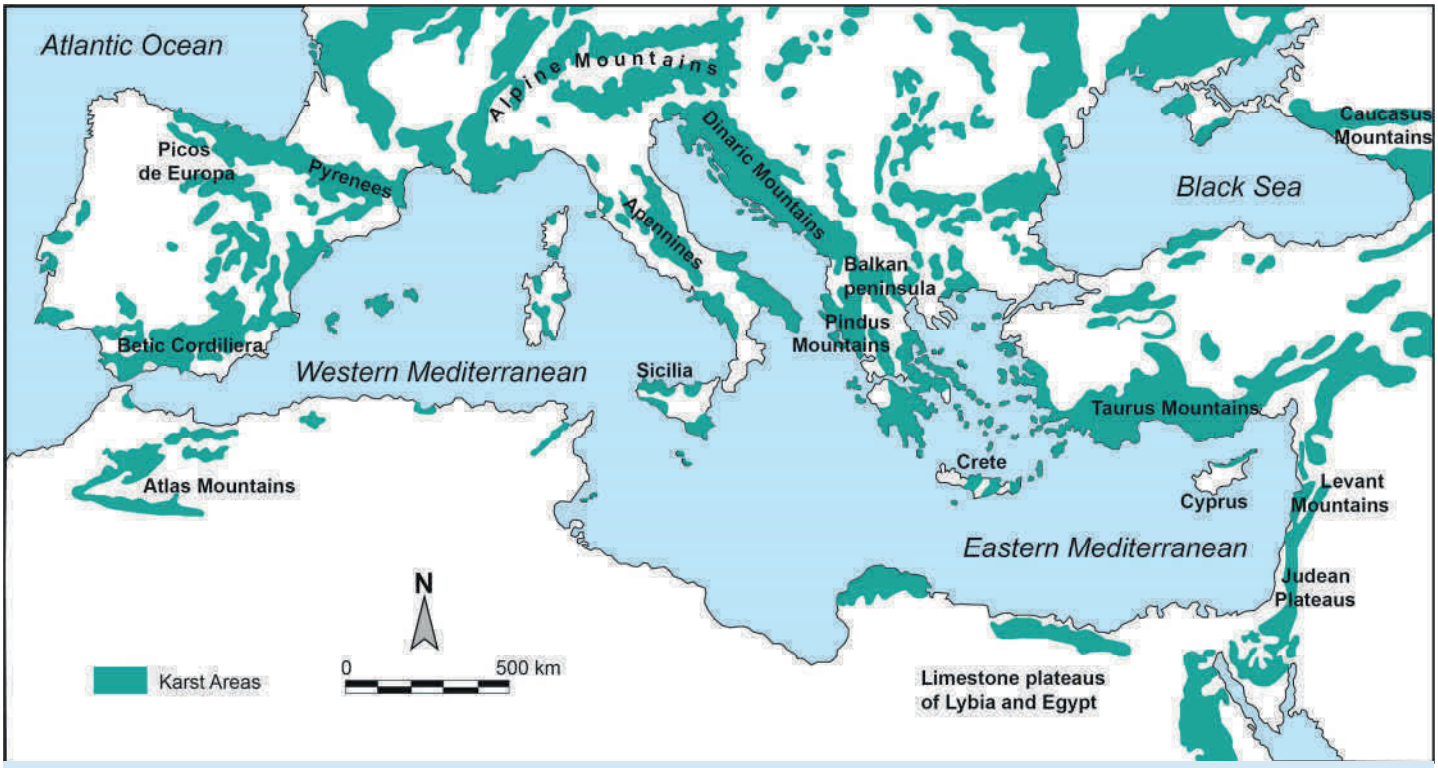
Kyrenian range (Cyprus)
Ph. Didier Cailhol

About 12% of the earth's continental surface is covered by carbonate rocks (limestone, marble, dolomite). This proportion is considerably higher in the Mediterranean basin and contributed, along with climate and vegetation in shaping the physical geography of the Mediterranean basin. Indeed, the limestone landscapes shaped by karstic processes are one of the defining characteristics of the Mediterranean environment. The nature and evolution of the karst landscapes across the basin displays however a spatial variability due to contrasts in topography, climatic history, bedrock composition and structure. Carbonate rocks are especially common in the northern part of the basin (e.g. Spain, southern France, Italy, Balkan Peninsula, Turkey), where abundant precipitation lead to solutional weathering for an extended geological period. This part is particularly flanked by mountains with uncovered limestone hillslopes drained by short and steep river systems whose headwaters commonly lie in well-developed karst areas. Karst features are also well developed specifically along the high mountain massifs in the Eastern (e.g. Lebanon, Israel/Palestine, Syria) and Western parts of the basin (e.g. the Atlas Mountains of Morocco and Algeria), while relict karst phenomena can be identified in the low-relief desert regions of Libya and Egypt .




*The distribution of the major outcrops of carbonate rocks (limestones, dolomites, marble) in the Mediterranean basin and concentrating the major karst phenomena along mountains areas and high-plateaus. Note that other limestones with well-developed cave systems are overlain by non-carbonate rocks and not showed in this map.*

## GEOLOGY OF THE MEDITERRANEAN BASIN

The Mediterranean is a relic ocean basin, representing the final stage of closure of the Tethys Ocean prior to the collision of the African continental plate in the South with the Eurasian plate system in the North. The basin nowadays is located over three tectonic plates (e.g. the African plate in the South, the Eurasian plate in the North, and the Arabian plate in the East), some is divided into a series of microplates (e.g. Ionian, Aegean, Turkish plates) mostly in the North-Eastern part of the basin.

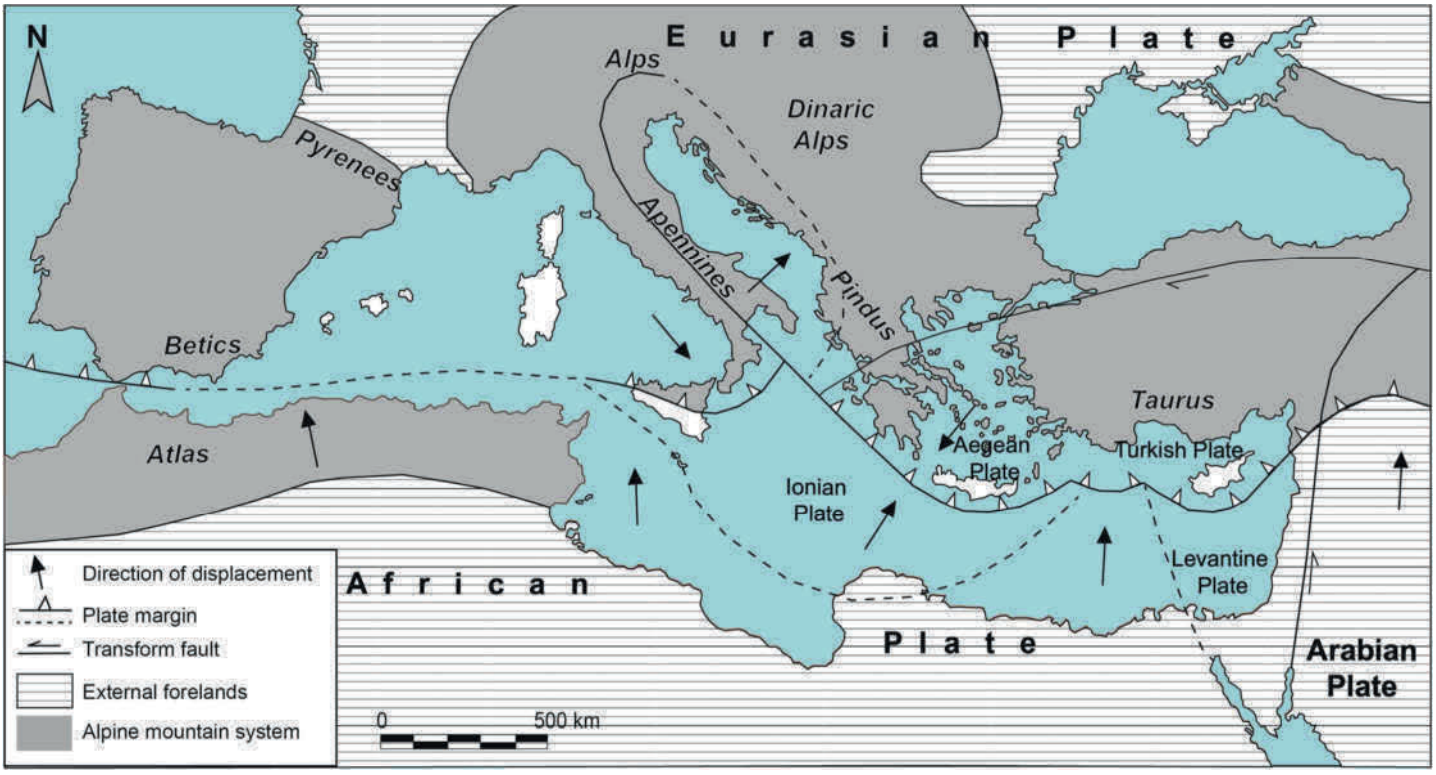
After the sedimentation of limestone rocks, including shallow lagoonal, reef, and deeper ocean facies around the open Tethys Ocean several hundred million years ago, the interaction between these plates led to the development of Alpine mountain systems during the Cretaceous, Palaeogene, and Neogene periods (from 145 to 2.5 Million years). Such folded and faulted mountains were uplifted up to 4,000 m altitude in some parts and comprise the North African Atlas, the Betic cordillera in Spain, the Alps extending from France to the Balkan Peninsula, the Apennines, and the Taurus in Turkey. The tectonic activity continues nowadays, especially in the North-Eastern part of the Mediterranean, where subduction and faulting are highly active South of Crete and Turkey. The extension of this major phase comprises also the uplift of the Iberian and Anatolian plateaus.

In the Southern and Eastern Mediterranean, a series of marine transgression and regression since 250 Million years ago lead to the deposition of marine and terrestrial sediments, but with less intense tectonic deformation than in the Alpine

mountains. The interaction between the African and Arabian plate along the Levant active fault led to the uplift of a narrow but high-elevated mountain massif from Northern Syria to the Judean plateau in Israel/Palestine. The prominent hilly and incised landscape is located in the mountainous Lebanon where elevations exceed 3,000 m.

The development of a fringe of less deformed limestone along the Eastern Mediterranean coast is different in appearance and character to the extensive and almost horizontal (low-elevation) limestone plateaus in Libya and Egypt. The elevations on the limestone plateaus in Egypt and Libya are generally below 1,000 m, with extreme aridity resulting in their partial coverage by sand.

Other limestone areas have a lower degree of deformation and sometimes local relief formed in continental basements or ocean floors which have been little transformed. These include parts of Eastern Spain, the Grand Causses in France with upland plateaus incised by 500-m deep valleys, and the Apulian coast in Italy.




*The tectonic setting of the Mediterranean basin showing the plates interplaying in the deformation of the Mediterranean. The derived mountains mentioned in the text are mostly from the Alpine mountain system built under several uplift cycles, since ~145 Million years ago.*

The most characteristic geological period that shaped the karstic landscapes in the Mediterranean basin covers the last 6 Million years, from the remarkable Messinian (Late Miocene) drying of the basin around 5.5 Million years, followed by the Quaternary sea level change (order of 120 m) during the glacial-interglacial cycles. The most dramatic episode in the history of the Mediterranean Sea is the Messinian Salinity Crisis (MSC), between 6 and 5 Millions year, during which the Mediterranean was isolated from the Atlantic Ocean, leading to its partial desiccation. During this time, large saline lakes replaced marine basins while some areas dried out completely, leading to the accumulation of thick evaporitic deposits. The sea-level fall during this period led to the development of large canyons downstream of the major river systems (e.g. the Rhone, the Nile). This base level fall also led to the development of very deep karst systems that lie well below present sea levels (see coastal karst). Non-limestone rocks may also develop karstic forms through dissolution: these include evaporites such as halite (rock salt) and sulphate rocks such as gypsum and anhydrite. These rocks, referred to as gypsum karst, are well developed in various parts of the Mediterranean region as a legacy of the Messinian Salinity Crisis, such as in the Betic Cordillera, the Apennines, Sicilia, Crete, Cyprus, Southern Turkey, and in the Levantine shelf.

## MOST RELEVANT SURFACE KARST PHENOMENA

Resistant limestones commonly form a hilly landscape in the Mediterranean combined with deeply entrenched valleys to make limestone massifs a dominant element in the region. Surface karst features along these limestone massifs are mostly controlled by the geological history, the tectonic evolution on the regional/local scale, but also by the climate (e.g. rainfall system, seasonality). Therefore, surface aspects of karst landscapes are different in the Northern compared to

Lefka Ori (Greece)
Ph. Theophile Cailhol

the Southern parts of the basin. as well as at higher altitudes compared to karst features at lower altitudes. For example, the Pyrenees, the Alps and the southern Adriatic coast receive over 1,500 mm precipitation as snow cover and annual rainfall may exceeds 4,500 mm in the mountains of Montenegro. High precipitation in these areas conduct to more active karstic processes compared to landscapes located at low altitude or to the dryland karst of the southern Mediterranean.

The alpine bare 'high and cold' karst located above 3,000 m, is conditioned by the effect of glaciers that shaped the thick limestone sequences through filled dolines, karren, sinkholes and glacially scoured bedrock pavements. The glaciation cycles combined with the fluvial incision for thousands of years, developed deep valleys and gorges. Such landscapes characterize the dolomites in the Italian Alps, the Pyrenees, the Pindus Mountains of North-West Greece, the High Atlas of Morocco and the Taurus Mountains of Turkey.

The hill karst located below 2,000 m is covered by much more residual soil than the karst located at a higher altitude. Much of the surface features characterizing the hill karst landscape, comprise funnel-shaped dolines of several dimensions, sinkholes, pinnacles and poljes (e.g. flat-floored depressions). Such surface phenomena are abundant in the Di-

Planinsko polje (Slovenia)
Ph. Didier Cailhol

naric mountains in Slovenia, from Croatia to the Montenegro and along the northern Levantine mountains (Syria, Lebanon).

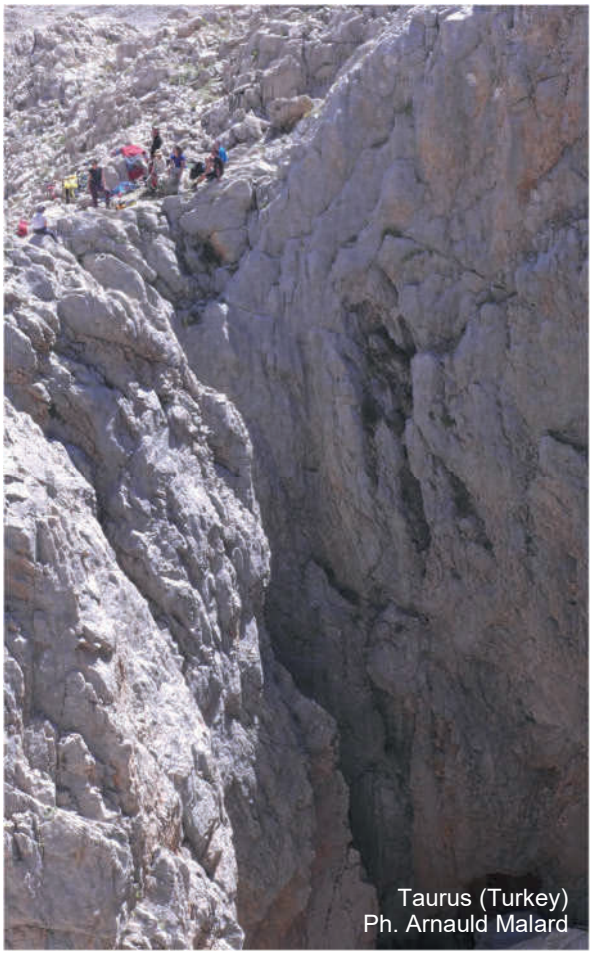
The dryland karst is more common in Southern Mediterranean, specifically in the limestone plateaus of the Egyptian and Libyan desert. Even though the hydraulic gradients are shallower and the water fluxes much lower, the dryland karst comprises surface features that developed under wetter climates several million years ago. Such surface phenomena comprise pavements and white chalk pinnacles, that emerge from a cover of desert sand. Thousands of these pinnacles are present in the white desert of the Farafra Oasis (Egypt) along with small areas of karst towers. In other areas such as Jabal al Akhdar in Eastern Libya, surface karstic features such as large sinkholes and cave systems are also developed along the North African coast.

White desert (Egypt)
Ph. Michael Hoefner

## MOST RELEVANT UNDERGROUND KARST PHENOMENA

The Mediterranean region is known for the abundance of limestone cave and cavern systems and contains some of the longest and deepest karst aquifers in the world, with many extending deep below the present sea level. A key feature of Mediterranean karsts is their extensive vertical development, due to the region's distinctive geological and geomorphological history. Many karst aquifers in the northern part of the basin therefore contain multiple levels of passages and these are often joined by very deep vertical shafts. The recent updated catalogues of cave systems in the Mediterranean report on cave systems located within the thick carbonate rocks, such as the Réseau Jean-Bernard (- 1,626 m) and Goufre Mirolda (- 1,733 m) in Haute-Savoie, France or the Čehi 2 cave (- 1,505 m) in Slovenia, the Lukina jama - Trojama cave system (- 1431 m) in Croatia and Egma Sinkhole (– 1,429 m) in Turkey. Note that the deepest cave systems in the world are located in the surroundings of the Mediterranean basin, specifically in the South Caucasus region (e.g. Veryovkina – 2,212 m; Krubera-Voronja – 2,197 m; Sarma – 1,830 m) and in the Picos de Europa, Northern Spain (e.g. Torca del Cerro – 1,589 m).

Other particular features of the underground karst systems in the basin are the abundance of active karst springs, which discharge are among the highest in the world. More than dozens of the karst springs in the Mediterranean show a discharge higher than 20 $m^3/s$ and drains a catchment area larger than 500 $km^2$. The three largest springs in the region are from Trebišnjica in Herzegovina, Bussento in Italy, and Dumanli in Turkey.



Taurus (Turkey)
Ph. Arnauld Malard

| Country | Region | Name | Vertical range (m) | Lengh (m) | Type of underground karst phenomena |
|---|---|---|---|---|---|
| Spain | Karst de Sorbas Almeria | Cueva de Agua | | 8,350 | Gypsum cave |
| | Karst de Sorbas Almeria | Cueva de Agua | | 4,245 | Gypsum cave |
| | Mallorca | Covas des Pas de Vallgornera | | 73,000 | Coastal and hypogenic |
| | Murcia | Higuera | | 5,300 | Hypogenic |
| | Murcia | Destapada | | 3,700 | Hypogenic |
| | Murcia | Puerto | | 4,389 | Hypogenic |
| France | Haute-Savoie | Réseau Jean-Bernard | -1,626 | | Epigenic and alpine cave |
| | Ardèche | Saint-Marcel | -287 | 62,000 | Paragenetic and sump |
| | Ardèche | Goul de la Tanerie | -242 | 1,400 | Sump |
| | Pyrénées-Orientales | Font Estramar | -262 | | Sump |
| | Alpes-Maritime | Mescla | -267 | | Sump and hypogenic |
| Italy | Toscane | Abisso Paolo Roversi | -1,360 | 4,429 | Epigenic cave |
| | Toscane | Complesso del Monte Corchia | -1,187 | 65,000 | Epigenic and alpine cave |
| | Sardinia | Sorgente Su Gologone | -135 | | Sump |
| | Sardinia | Grotta del Fico | -70 | 1,980 | Flank margin cave |
| | Emilia Romagna | Spipola-Acquafredda | -110 | 10,400 | Gypsum cave |
| | Sicilly | Grotta di Santa Ninfa | -48 | 1,470 | Gypsum cave |
| | Marche | Grotta di Frasassi | -300 | 5,000 | Hypogenic cave |
| | Sicilly | Monte Conca | -130 | 2,400 | Gypsum cave |
| Italy-Slovenia | Friuli-Kras plateau | Reka-Timavo Karst system | -450 | 50,000 | Epigenic, ponor, cave system, karst spring |
| Slovenia | Slovenia Trenta Valley - Rombon | Čehi 2 cave | -1,505 | | Epigenic and alpine cave |
| Croatia | Velebit | Lukina jama | -1,392 | | Epigencic and alpine cave |
| | Velebit | Slovačka jama | -1,320 | | Epigencic and alpine cave |
| | Velebit cave system | Near Crikvena | -1,026 | | Epigencic and alpine cave |
| | Ogulin-Karlovac region | Dula-Medvedica | | 16,384 | Epigenic and ponor cave system |
| | Biokovo massif | Crveno jezero | -245 | | Sump |
| Greece | Falakro Mountain | Aggitis cave | -370 | 11,700 | Ponor sump and river |
| | Crete | Gorgotakas | -1,207 | | Alpine cave |
| | Crete | Lion Shaft | -1,100 | | Alpine cave |
| | Peloponnese | Diros cave | -200 | 1,500 | Epigenic cave |
| | Tymfi mountains | Provatina | -407 | | Alpine cave deep shaft |
| | Athens | Vouliagmeni | -105 | 1,200 | Sump, marine spring and hypogenic |
| Turkey | Anamur district | EGMA sinkhole | -1,429 | 3,118 | Epigenic cave |
| | Aladaglar massif | Kuzgan cave | -1400 | 3,187 | Epigenic cave |
| | Antalya | Dumanli Spring | | | Karst spring |
| Lebanon | Mount Lebanon | Jeita cave | | 10,050 | Epigenic, cave system, spring |
| | Mount Lebanon | Roueiss cave | | 5,460 | Epigenic, cave system, spring |
| | Mount Lebanon | Afqa cave | | 5,260 | Epigenic, cave system, spring |
| | Mount Lebanon | Fouar Dara | -622 | | Epigenic, alpine cave |
| | Mount Lebanon | Qattîne Azar | -515 | | Epigenic, alpine cave |
| Cyprus | Kyrenia | Pentadactylos | -200 | | Deep shaft, tectonic |
| Morocco | Middle-Atlas | Kehf Tikhouabi | -310 | | Alpine cave deep shaft |
| | Middle-Atlas | Chaara | | 7,650 | Active, underground stream |
| | Middle-Atlas | Friwato | -271 | | Alpine deep shaft |
| | High-Atlas | Ifri N'ataouia | | 3,600 | Active, underground stream |

List of the most important featured caves in the Mediterranean basin (deepest and longest, caves with particular features related to the MSC). The vertical range is the difference between the altitude of the highest entrance and lowermost point reached in the cave. Some caves extend below the local water table and are water-filled. The length is the explored and mapped galleries known to day. The type of karst phenomena details the cave origin, category and characteristics.

## COASTAL KARST

The karst of the Mediterranean Basin has recorded important sea-level evolutions since the Messinian Salinity Crisis (MSC) until the last Holocene warming (last 10.000 years). Such geological and climatic changes impacted the Mediterranean water extension over the years and shaped the coastal karst with unique phenomena: deep multi-level caves near or below present sea-level, archeological caves below sea-level, marine springs, hypogenic processes, etc. For example, the present-day settings of the Mediterranean coastline with 46.000 km long were reduced or extended over the past and therefore impacted the underground karst development, deepening the levels of some caves or submerging others located on shore. During the different phases of the MSC, the lowering of the Mediterranean Sea-level induced an active karstification with the deepening of caves and the development of multi-level caves systems following the intrenchment of deep river canyons. Different types of water drainage were established then. The Port Miou spring, in the Callanques of Marseille-Cassis, is a typical karst system for the named model "*next to the present Mediterranean shoreline*". Another typical example is the karst of the Rhône Valley with its deep cave systems linked to the Fontaine de Vaucluse. This karst system is representative of the aquifers connected to canyons entrenched during the Messinian (5.6 Million years ago) and later drowned during the Pliocene (3.5 Million years ago).

Another karst model inherited from this geological period (MSC) is the inland remote karst system which is known nowadays as karst offshore springs. These systems have initially hydrogeologic deep connection with the continental shelf and therefore can transit deep water to discharge offshore where the aquifer is locally breached by the Messinian erosional surface. Such karst offshore springs are present in some of Northern and Eastern parts of the basin, as in the Golf of Lion, France, in the Lili spring, Peloponnese, Greece and the submarine springs of the Chekka bay in Lebanon.

Since the last 10.000 years (Holocene), the Mediterranean Sea level was rising continuously and submerging many coastal cave systems located onshore. For example, Diros Cave, in the Peloponnese, with its 200 m vertical range (70 m underwater) is a typical cave which was impacted by the sea-level evolutions during the Pleistocene glaciation cycles and by the present sea-level rise since the Holocene warming period. Another example is The Grotte Cosquer near Marseille, France which is known for its Paleolithic Rock Art. The continuous rise of the present-day sea level threatens the last painting and archaeological remains located in the upper galleries.

Croatian shore
Ph. Didier Cailhol

Other particular phenomena along the Mediterranean coast are the deep hypogenic processes with carbonic or sulphuric acid, leading to the development of a specific cave system in the Mediterranean Islands such as in Sardinia, Sicily and Mallorca. For example, the Cova des Pas de Vallgornera, in Mallorca is 78,0000 m long, known to be among the 30$^{th}$ longest cave in the world. This maze cave is known to develop near the sea level, with more than 17,000 m of submerged galleries. The importance of the cave is not only related to its extension, but also to the presence of a wide variety of speleothems and outstanding solutional morphologies that evidence a complex evolution related to both hypogenic processes and mixed dissolution processes between fresh groundwater and saltwaters.

The latter process is known worldwide where limestone shore cliffs exist. At the sea/groundwater interface, an aggressive solution derives from the mixing between saline and fresh water and develops specific dissolution morphologies along the cave walls. Such processes are particular for the "flank margin caves" which are present in some coastal areas of the Mediterranean (e.g. the Apulia limestone coasts in Italy, the Antalya shores in South of Turkey and the coastal cliffs of Croatia).

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# MEDITERRANEAN KARST GROUNDWATER RESOURCES

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The Peschiera spring in the Apennine mountains in central Italy is used for the freshwater supply of Rome since the 20th century. The average total discharge is about 18 m³/s, among which 9 m³/s are tapped for drinking water and 9 m³/s are released to the environment, to ensure ecological minimum flow of the downstream flowing water ecosystems. The spring is situated in a large mass movement at the bottom of an extended mountainous carbonate rocks massif, and taped by means of several artificial drainage galleries dug into the strongly fractured carbonate rocks. The region is strongly afected by earthquakes. Ph. Nico Goldscheider

Since earliest antiquity karst groundwater resources play an essential part for economic activities of most Mediterranean countries. The earliest settlements developed around springs, pushed by the scarcity of permanent surface flows. Water works gradually improved the capacity to exploit more water as settlements increased in size. Aqueducts were the most important technological advance, probably invented by the Phoenician people at the end of the 2nd millennium BCE. They made it possible to build cities far from water sources to take advantage of favorable locations, such as harbors or plains suitable for cultivation.

Early cities and kingdoms often originated in the vicinity of karst springs, which, as well as karst features, inspired their mythologies. For instance, the cosmogony of ancient Greece and Plato's water cycle theory were completely inspired by karst environments. Plato believed the water cycle was driven by internal subterranean forces that “pump” water upwards from the Tartarus to feed the mountain springs that give rise to all rivers. Well known in Greece, caves, underground rivers and large springs certainly inspired this theory. Karst groundwater must thus be considered as the source of European myths and conception of the hydrological cycle and of the world’s structure.

Carbonate formations and karst features are extensively developed not only in Greece, but throughout all Mediterranean regions. Since “the Mediterranean basin is the cradle of karstic studies” according to Ford and Williams, “Mediterranean” karst is considered by many authors as an international reference for karst geomorphology and hydrology. However, the complex geological history of the Mediterranean produced various conditions that distinguish this complex karst from other karsts of the world. The geological history of the Mediterranean especially includes frequent and dramatic base-level changes since at least the late Miocene. The summary presented below shows various conditions in the development and abandonment of karst structures that make Mediterranean karst original and complex.

In 1998, Jean Margat estimated that carbonate outcrops cover at least 15% of the surface of the Mediterranean catchment area and that carbonate aquifers supplied at least 25% of domestic water supply, not counting industry, agricultural,

Foux de la Vis spring (Languedoc, France).
Spring previously used for water mills, now for a hydraulic turbine. It discharges groundwater from the Larzac plateau, North of Montpellier.
Ph. Michel Bakalowicz

and tourism withdrawals. Groundwater from carbonate aquifers is consequently of major importance for development in Mediterranean countries. Using data and procedures developed within WOKAM, the KARMA project is re-assessing the effective contribution of karst groundwater resources to economic activities in the Mediterranean basin.

Fig. 1 is a map of Mediterranean carbonate outcrops. Large springs emerge from them, what indicates that karst processes have affected most if not all carbonate formations, as shown by the remarkable development of karst landforms. All along the Mediterranean coast submarine and coastal springs discharge. They represent at least 90% of the known submarine karst springs in the world, what is the most important characteristic of “Mediterranean” karst.

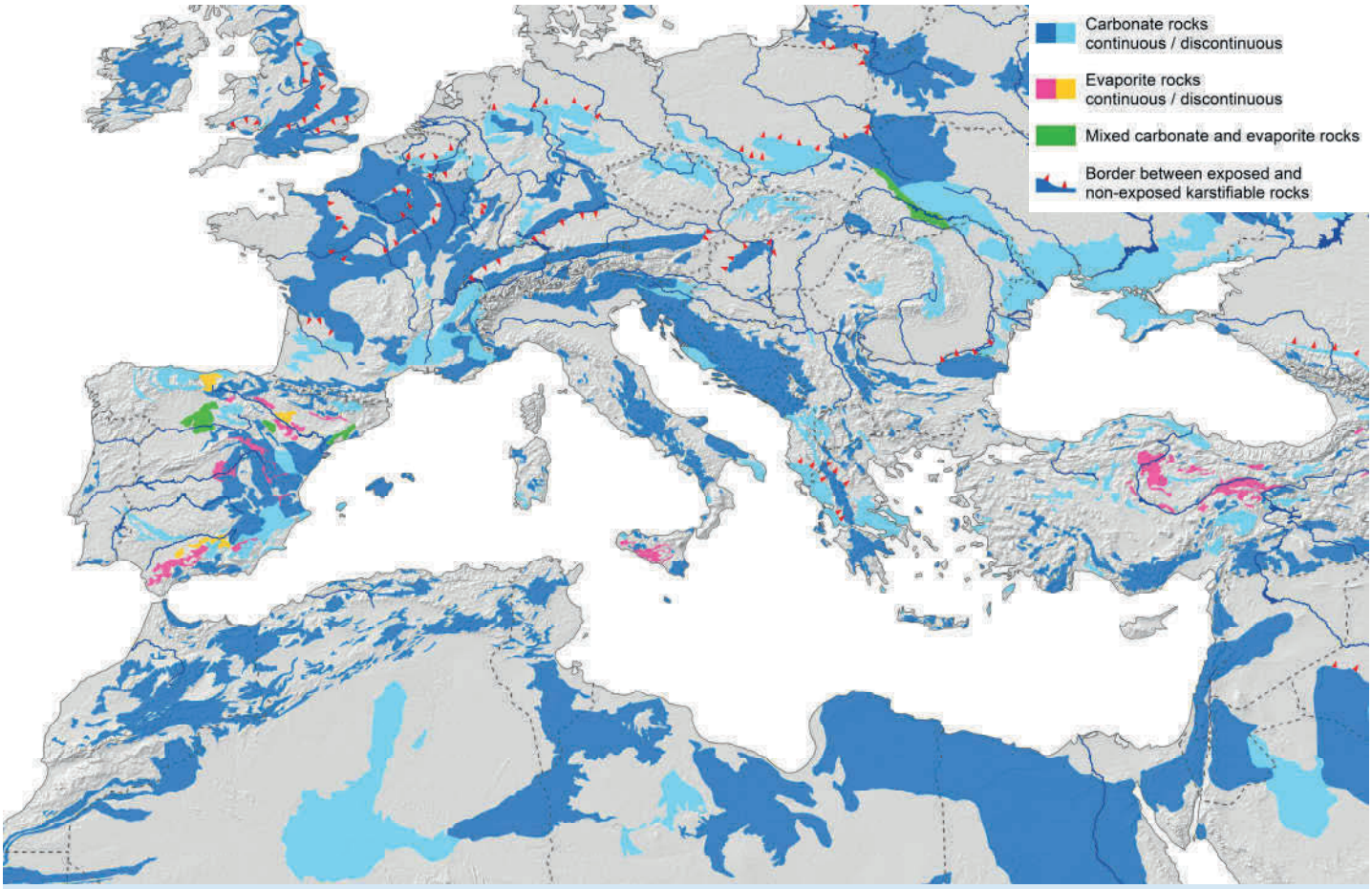


Fig. 1. Map of Mediterranean carbonate outcrops (from WOKAM)

## GEOLOGICAL SETTINGS OF THE MEDITERRANEAN AREA AND ITS CARBONATE FORMATIONS

The Mediterranean basin is all that remains of the Alpine portion of the Tethys Ocean that was located between the Iberian, Eurasian, African, and Arabian plates. Northward movement of the African and Arabian plates almost closed this basin during the Tertiary and Quaternary. The continental margins were the location of abundant carbonate sedimentation under tropical conditions since the Late Triassic. However, long periods of emersion during the Late Jurassic, Early Cretaceous, and Oligocene and since the end of the Miocene have led to local karst development. Tropical climatic conditions, especially during the Early Cretaceous, favored the formation of lateritic accumulations that resulted in bauxite deposits, often preserved in paleokarst landscapes.

The intense tectonic activity related to plate movement formed the Alpine belt that surrounds the basin. This activity caused the uplift, faulting, folding, and fracturing of carbonate formations. Extensional tectonics during the Miocene, Pliocene, and Quaternary created rift systems (Greece, Turkey, Middle-East, and Maghreb) often associated with hydrothermalism and deep $CO_2$ flux (e.g. Algeria, Greece, and Turkey). The extensional tectonics also provided favorable conditions for infiltration and groundwater flow under significant hydraulic gradients due to the steep topography. Frequent periods of climatic conditions ranging from tropical humid to Mediterranean favored carbonate dissolution. Abundant annual rainfall and mild-to-warm temperatures promoted the growth of dense plant cover that produced soil $CO_2$ and favored significant infiltration. These conditions do not differ greatly from other karst areas in the world, but these

karst-development conditions are sufficiently varied to produce different karst aquifer types, and not a single unique Mediterranean type as some researchers still claim.

An unusual but probably not unique geological event, the Messinian Salinity Crisis (MSC), occurred only in the Mediterranean basin; between 5.96 and 5.33 Ma, sea level dropped by more than 1500 m. The strait connecting the Atlantic Ocean to the Mediterranean closed tectonically, stopping flow from the ocean that had offset the water deficit caused by evaporation. Since the beginning of the Miocene, the Mediterranean had a negative water balance because evaporation exceeded, and still exceeds the fresh water inflow. This deficit had previously been offset by inflow from the Atlantic Ocean. For the Mediterranean itself, the primary consequences of isolation from the ocean were a 1500-to-2500 m drop in sea level and the formation of small isolated hypersaline basins where thick gypsum and salt were deposited.

Because of the tropical humid climate of the surrounding continents, the main rivers continued to flow and incise the continental shelf to reach the basin floor, creating valleys several hundred meters deep, such as the valley of the Rhone River, which extended north to Lyons, and that of the Nile River which then extended to Aswan. The drastically lower base level lasted several hundred thousand years until the opening of the Strait of Gibraltar; it caused the development of karst drainage throughout all levels of carbonate rock outcrops to depths much below the present sea level.

The MSC ended abruptly; Atlantic waters flooded the entire basin and the deep river valleys in a few tens of years: this is the Zanclean transgression marking the beginning of Pliocene, and characterized by significant sedimentation of marine blue clays several hundred meters thick in some places, overlain by Gilbert delta formations, controlled by the main rivers. The thick sedimentation, however, did not occur everywhere along the coasts; instead, it left large areas of coastline devoid of impermeable sediments.

Finally during the Plio-Quaternary the entire region was subject to climate change, ranging from a Mediterranean climate during interglacial periods to ice age periods with alternating high (about present level) and low sea levels (about -120 m below present). While low stages of sea level contributed locally to karst development below the present sea level throughout the world, in the Mediterranean basin they locally rejuvenated karst landforms inherited from the MCS. In all high-mountain areas, the colder periods actively promoted the karst weathering through the erosional action of local glaciers and firns but primarily through the removal of vegetation and soils, intense weathering of epikarst, and related scree accumulation. As a result, the high-mountain karst features of Slovenia, Croatia, Montenegro, Greece, Turkey, and Lebanon are commonly coated with a thick scree cover.

Afqa spring, (Lebanon Mountains).
Spring typical of high mountain karst systems. Left: during low flow stage. The red circle shows an individual as a scale. Right: during snow melt flood. Ph. Michel Bakalowicz

## CONSEQUENCES ON KARST DEVELOPMENT AND KARST GROUNDWATER RESOURCES

Since the Oligocene, most Mediterranean carbonate formations have been subject to karst processes. We can say that all limestones and dolostones are karstified and present a hydrological karst function. Frequent base-level changes related to uplift, subsidence, or sea level change controlled the development of multiphase conduit systems in most carbonate formations. Depending on the location of a carbonate formation in the Mediterranean basin, this multiphase de-

velopment had quite different consequences on aquifer characteristics. The effects of karst processes differed greatly according to morphological situation and proximity to the sea.

Based on this complex geological history, three main domains can be distinguished as a result of differing conditions of karst evolution: I) ***the high-mountain domain***, where uplift conditions prevailed; II) ***the domain of inland plateaus, basins, and grabens***, subject to uplift along their margins and subsidence of the basins; and III) ***the coastal domain*** where karst development was driven mainly by sea level changes and especially the MSC. The resulting karst systems of each domain share specific common aquifer characteristics, which differ from those of other domains.

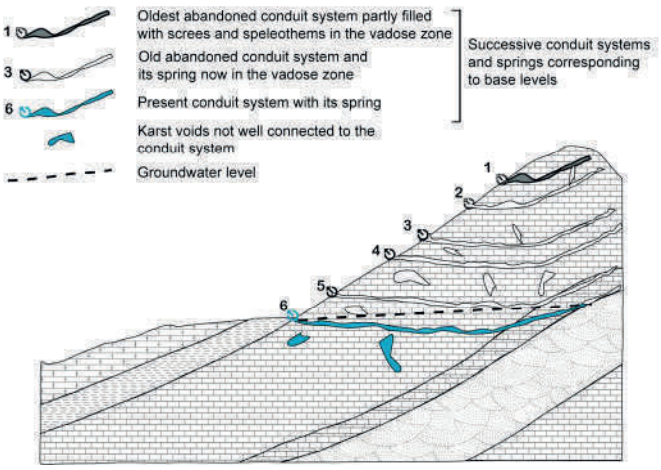


Fig. 2. High-mountain karst systems.

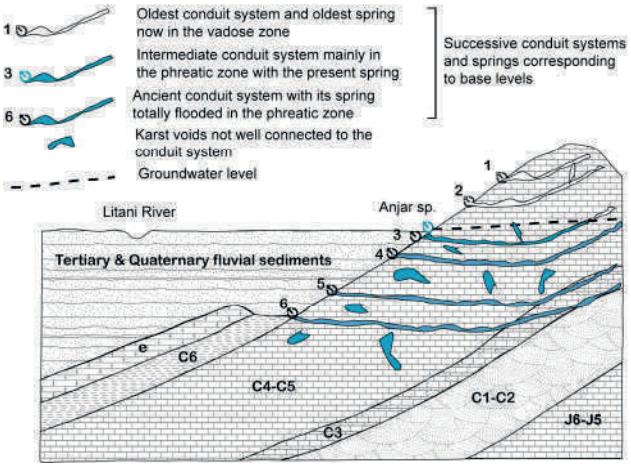


Fig. 3. Karst systems related to basins and grabens. Conduit systems developed during a regional uplift followed by the closing and the sediment infilling of the basin. From the example of the Anjar-Chamsine system, the Bekaa plain, Lebanon (after El Hakim 2005).

## HIGH-MOUNTAIN KARST SYSTEMS

This domain has undergone continuous uplift since at least the Oligocene, then subject to a constant dropping of the karst base level. Conduit systems are generally superimposed, the lowest conduit being functional and the uppermost integrated into the infiltration zone (Fig. 2). Tectonics may have created major discontinuities such as overthrusts and faults along which impermeable formations (e.g. flysch) favored the formation of surface flow and large closed depressions or poljes drained by swallowholes. Consequently, the karst systems may be extensive and may discharge at large springs characterized by typically high seasonal variations of their hydrological and geochemical parameters. This is the typical karst of Slovenia and Croatia, common in the whole Alpine range, and in the Lebanon mountains. Some springs may have high mean discharges, up to some 10 m³/s and a flow rate variability, expressed as a ratio $Q_{max}/Q_{min}$, often more than $10^3$. Their dynamic storage calculated from recession is relatively low, generally less than 50 $hm^3$, considering their large extent. Their infiltration conditions are often characterized by slow recharge because of the abundant scree cover that coats all karst depressions and the remains of the epikarst.

## KARST SYSTEMS RELATED TO INLAND BASINS AND GRABENS

Despite their different tectonic settings, basins and grabens show similar conditions of karst development. The main difference lies in the fact that the extensional tectonics that generated the grabens may contribute to the upward flow of deep, thermal groundwater often enriched in deep $CO_2$. Extensive basins may develop behind mountain ridges. Most of these basins were uplifted, such as the Anatolian plateau north of the Taurus Mountains, the series of depressions east of the Lebanon Mountains, the Bekaa and the Ghab plain. Grabens occur in carbonate formations in Greece, Turkey and Algeria.

In both cases Miocene, Pliocene and Quaternary tectonics are responsible for a general evolution of karst following two different successive patterns (Fig. 3). The initial step is similar to high mountain karst systems with the development of multiphase karst systems. Then, the basins or grabens were closed and filled with alluvial sediments that progressively coated the springs and plugged the lower conduit systems, raising the base level, progressively flooding and confining the previous drainage structures. These karst systems now overflow at the new base level; their storage capacity may be huge, depending on the alluvial fill thickness and on the development of karst voids below the present base level.

Ombla Spring, located on the Adriatic coast near Dubrovnik, Croatia, is one of the largest springs of the Dinaric karst region, with a minimum, mean and maximum discharge of about 4, 24 and 138 m³/s respectively. Originally, the spring discharged at sea level, but a small dam (2.4 m high) was constructed 50 m downstream of the spring orifice to avoid seawater intrusion. The spring water is used for the freshwater supply of Dubrovnik since 1897. Ph. Nico Goldscheider

For instance, in the central part of the Bekaa plain, which is at an elevation of about 1000 m, the alluvial fill is more than 400 m thick. It has been shown that karst features developed at depth below the level of the plain are responsible for the huge storage capacity of karst aquifers that discharge at the foot of the Anti-Lebanon Mountains. The springs are characterized by a mean discharge of several m³/s, a huge dynamic storage more than 100 $hm^3$, even exceeding 1000 hm³ and a very low flow rate variability, less than 0.2.

In Algeria, the carbonate formations of the Constantine and Saida areas are characterized by recent to present horst and graben tectonics. River valleys have developed in the grabens where the aquifers discharge; recharge occurs on the horsts. Alluvium forms shallow aquifers fed partly by upward groundwater flow from deep carbonate aquifers. These aquifers are karstified by concentrated recharge from surface runoff on impermeable Tertiary formations, which is swallowed at the limestone contact. However, the most efficient karst processes are related to the contribution of deep $CO_2$ carried by thermal waters. Comparable karst systems also occur in Greece and Turkey.

The name of this karst spring is “Fuente de los 100 Caños”, which means “spring of the 100 orifices”. It drains the Sierra de San Jorge karst massif in Andalusia, Spain. The spring is used for water supply and was officially declared Natural Monument of Andalusia in 2011. Ph. Nico Goldscheider

These two karst system types, with or without a contribution of thermal groundwater enriched in deep $CO_2$, offer an interesting resource for exploitation. The intense development of karst features in the phreatic zone at depth constitutes a large, and even huge storage capacity; this capacity permit the seasonal overexploitation of reserves that can be easily recharged during the rainy season. The exploitation of these complex karst systems is all the easier because they are often combined with shallow alluvial aquifers. Consequently the high productivity of wells, which makes it possible to irrigate large farming areas in semiarid regions and supply water to large towns, encourages the permanent overexploita-

tion of groundwater reserves in the absence of sustainable practices. Significant decreases of groundwater levels and spring discharge are becoming increasingly common. This phenomenon occurs particularly in the Middle East and Maghreb.

## KARST SYSTEMS RELATED TO THE MEDITERRANEAN SEA LEVEL CHANGES

Karst systems located along the Messinian coastline during the MCS appear to be unique among karst areas of the world. Huge conduit systems developed in a relatively short geological time, in carbonate formations, several hundred to several thousand meters thick. They ceased to function abruptly as a result of sea level rise and, in many places, sedimentation of marine blue clays. This MSC resulted in two different hydrogeological situations (Fig. 4).

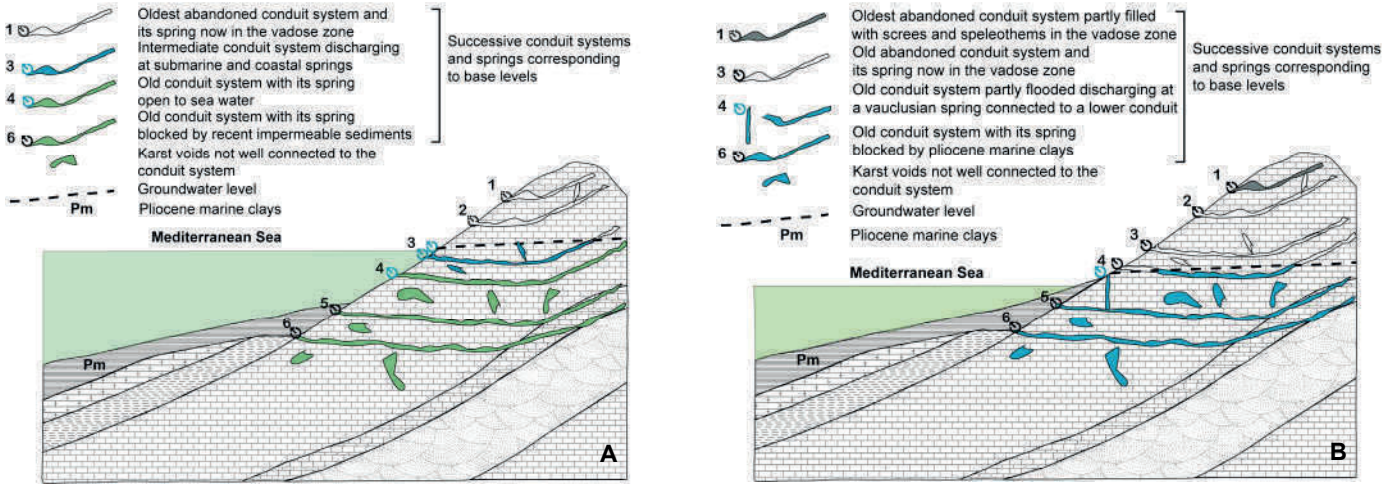


Fig. 4. Karst systems related to the Mediterranean Sea level changes in the coastal domain. A: Unplugged karst systems. B: Plugged karst systems.

### "Plugged" karst systems

The systems that discharged into the main valleys during the MSC became plugged with clays (Fig. 4B). Their characteristics can be compared to those of basins and grabens, i.e. a large extent that provides abundant resources and a large storage capacity. These are the Vaucluse-type or vauclusian springs, overflow of the phreatic zone after the plugging of the original springs. However, their conduit systems are typically too deep to be intersected by wells, except sometimes near the spring as in the case of the Lez spring, France.

In some cases, marine clays or other formations such as basalts may have plugged coastal aquifers, thus confining groundwater and preventing sea-water intrusion. This is the situation at the El Sin spring and Banyias karst aquifer in the Gulf of Bassieh, Syria and at the Gradole, Jadro, and Ombla springs in Croatia. These aquifers are exploited for water supply; their karst systems are the most suitable for an active management, using the significant reserves as a buffer to allow pumping groundwater at rates close to their mean discharge during the low flow season.

### "Unplugged" coastal karst systems

However, most carbonate formations along the coasts were either not covered with sediments or the sediments may have eroded during post-MSC periods. Consequently surface karst features such as sinkholes now flooded by sea water are generally connected to conduit systems that still function inland in the recharge area (Fig. 4). As long as the fresh water head in the conduits is higher than sea-water head, the karst systems discharge at submarine and coastal springs corresponding to these flooded karst features. Numerous coastal and submarine springs are known along the Mediterranean coast.

Various authors have used different methods to assess their discharge, including stable isotopes and remote sensing. Direct measurements and water balances show that discharges have been exaggerated by 5 to 10 times in the few studied cases. Even so, some of these springs have a mean annual discharge of several $m^3/s$, despite strong seasonal variations, which makes them interesting potential water resources in coastal areas that often lack water. This is the well documented case of Chekka Bay submarine springs, Lebanon. Because the conduit systems are open to the sea at different depths, sea-water intrusion occurs naturally, especially during the low flow stage. All submarine and many coastal springs discharge brackish water, at least during the dry season. It was shown that sea-water intrusion may occur some hundred meters below sea level.

As a result, these submarine springs are not exploitable, not only because of the low discharge during the dry season but also because of brackish water. Various tests have been done to capture submarine springs. The system that drives fresh or brackish water to the sea surface reduces the water head over the spring, which increases the sea-water head in the conduit, enhances sea-water intrusion, and raises the salinity of the captured water. Capturing “fresh” water from karst submarine springs thus appears to be an impossible challenge. It is much better to tap groundwater from inland wells, and monitor salinity and flow at submarine springs for reducing sea-water intrusion and preventing it by reducing pumping rate in wells.

The KARMA project (**K**arst **A**quifer **R**esources availability and quality in the **M**editerranean **A**rea, http://karma-project.org/ is an international project involving research teams from France, Germany, Italy, Lebanon, Spain, and Tunisia. Several external experts from France, Germany, Serbia, and Slovenia take part in it. It is an attempt to collect, produce and synthesize a maximum amount of data on Mediterranean karst aquifers. It has to demonstrate the great importance of karst groundwater resources in Mediterranean countries to encourage authorities to launch hydrogeological studies and develop hydrological databases necessary to propose long-term water policies that are able to cope with increasing climate variability, for sustainably exploiting these groundwater in order to avoid overexploitation, leading to pollution, sea-water intrusion and/or high pumping costs. This contribution is largely inspired by my article published in Environmental Earth Sciences in 2015, entitled "Karst and karst groundwater resources in the Mediterranean". It gives a complete list of references.

Lez spring Montpellier (France).
The spring is captured by 4 wells pumping about 1.6 $m^3/s$ for water supply of Montpellier Metropolis. The discharge is either the overflow during floods or a flow discharged from the pumping station during low flow, according to the environmental regulation. Spring typical of plugged karst systems related to the Mediterranean Sea level changes in the coastal domain. Ph. Michel Bakalowicz

# MAP OF ROCK-CUT SITES IN THE MEDITERRANEAN BASIN AND CLASSIFICATION OF THE RELATED HYDRAULIC WORKS

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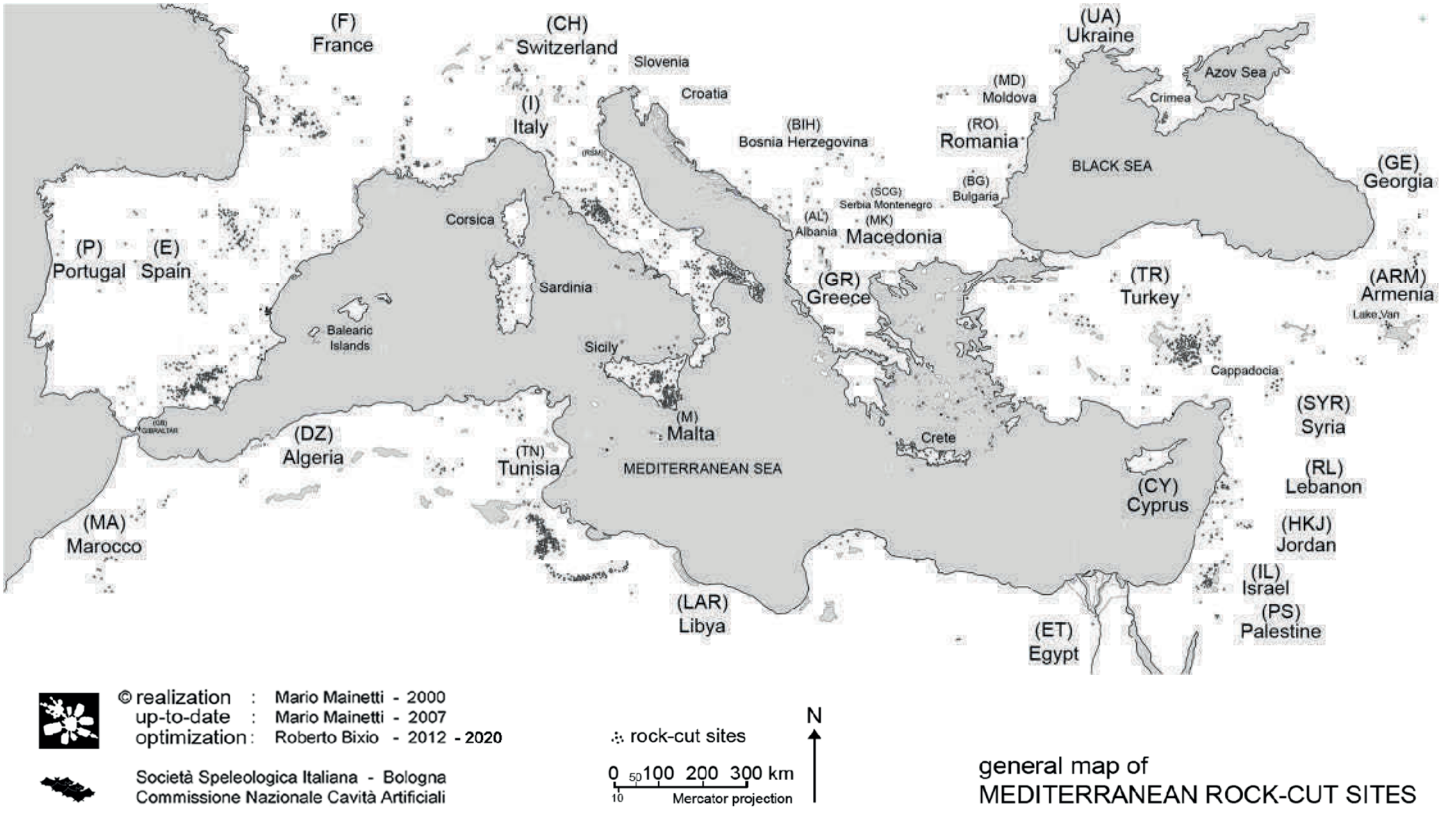
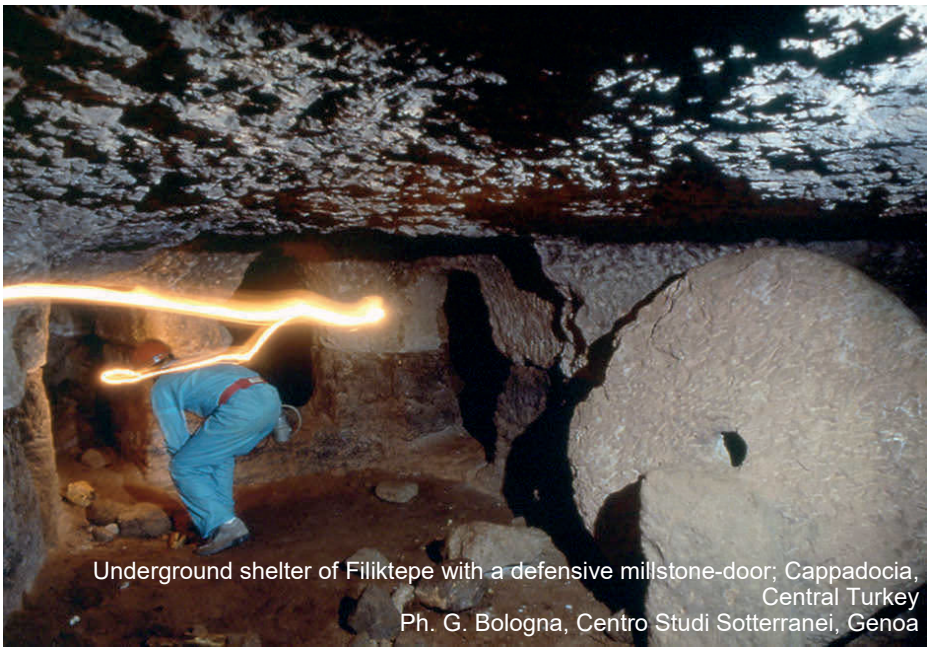
Remains of a Byzantine rock-cut church at Çanlı Kilise, later transformed into a dovecote; Cappadocia, Central Turkey
Ph. A. Bixio, Centro Studi Sotterranei, Genoa




Blooming of rupestrian communities is a significant phenomenon in central-southern Italy (southern Tuscany, northern Latium, Campania, Molise, Basilicata, Apulia and Sicily), and in many other countries of the Mediterranean Basin (Algeria, France, Libya, Malta, Greece, Morocco, Spain, Tunisia, Turkey), as well as of Africa (Ethiopia), the Middle East (Jordan, Israel, Syria), and central Asia (Armenia, Azerbaijan, Georgia, Turkmenistan). Further, it is also present in other regions of the world, from the ancient Persia, to China, to the high valleys in the Himalaya.

The speleological research in artificial cavities, which started in Italy and nowadays is widespread in many other countries, has largely contributed to acquisition of a large amount of data of great interest about the different typologies of cavities (civilian settlements, underground working places, defensive works, hermitage sites), and the structures necessary to daily life and to development of a variety of activities as well. Speleologists, by comparing the techniques used in the realization of the different works, and the related aims, have collected data about tens of thousands of underground sites excavated by man, of high historical and anthropological interest. Thanks to this work of many decades, we can today compare and analyze all these data, which in turn feed several projects, as for the case of the Map of Rock-Cut Sites in the Mediterranean Basin.


Underground shelter of Filiktepe with a defensive millstone-door; Cappadocia, Central Turkey
Ph. G. Bologna, Centro Studi Sotterranei, Genoa

The main goal of the project, initially started by two Italian researchers (Besana & Mainetti, 2000), and later on shared with the Commission of Artificial Cavities of the Italian Speleological Society (Bixio *et al.*, 2012), was to define size and distribution of a phenomenon involving so many countries in the world. The idea of preparing a list to highlight the actual distribution of

the subterranean architectures stands from the lack of a quantitative approach to the issue. This couples with the will to provide a sound basis for all the scholars interested in the study of cavities excavated by man, at all levels and with approaches which often are quite different from one field of research to the others. Another important point is that many underground works, which generally appear of lower interest, need actually to be analyzed within a more general framework, that is, the whole site where they have been realized; in this view, worship sites, defensive systems, rural structures, etc., acquire a new meaning and deserve, in turn, to be studied in detail, as well as in relation to the surrounding, both natural and man-made, settings.

Well for the water supply of the underground shelter of Göstesin, Cappadocia, Central Turkey
Ph. G. Bologna, Centro Studi Sotterranei, Genoa

At present, the work of inventory of Rock-Cut Sites in the Mediterranean Basin is still in the phase of being revised. In detail, in 2019 a first classification of the hydraulic works linked to rock-cut sites has been produced (Polimeni *et al.*, 2019; Galeazzi *et al.*, 2020): all registered water works, deriving from speleological studies, have been classified and subdivided on the basis of their typology, technique of realization and purpose, according to the internationally adopted classification of artificial cavities (Parise *et al.*, 2013).

The hydraulic works are necessary for the life of both civil and religious settlements (Bixio *et al.*, 2008, 2017). They aim at tapping water, to transport, accumulate and distribute the water resource, or to solve hydrological and geological hazards (draining the lands at risk of flooding, cleaning the thalwegs by flood deposits, etc.). This type of artificial underground works testifies – much more than the other types – the technical abilities in realizing ingenious underground systems, with simple but smart designs, developed in sustainable way with the surrounding environment, including the geomorphological and hydrogeological factors (Del Prete & Parise, 2013), according to the local climatic conditions and the history of the sites. In this case, too, all data belong to the wide speleological literature. The analysis has revealed a set of remarkable value, which includes those works previously considered as having less importance, and therefore previously ignored or scarcely investigated, also because they were in some cases more difficult to explore and document. In arid and semi-arid territories, where the challenge to find water is much more demanding for climatic reasons, the ability to supply with water the small and large settlements required in each epoch huge efforts (Parise & Sammarco, 2015), as testified by the wide variety of typologies of hydraulic works. In this sense, also the works realized by the religious communities, with particular reference to those of the hermit type, have a great interest, being structures

A settlement in Jordan
Ph. C. Germani, Egeria Centro Ricerche Sotterranee, Rome

typically of smaller size, since they were devoted to provide water according to a lifestyle closer to that typical of the desert. Aimed at increasing the inventory of Rock-Cut Sites in the Mediterranean Basin, data related to new, not yet documented, sites can be sent to the Authors, together with a synthetic description.

Settlement of Ani (Turkey)
Ph. R. Bixio., Centro Studi Sotterranei, Genoa

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# SACRED CAVES IN THE MEDITERRANEAN

## THE SPREAD OF THE CULT OF SAINT MICHAEL BETWEEN EAST AND WEST

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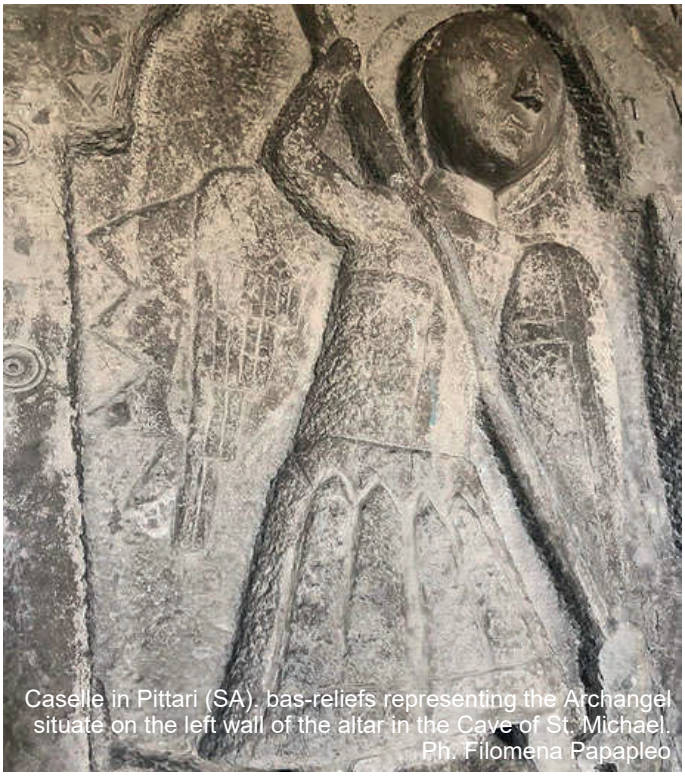
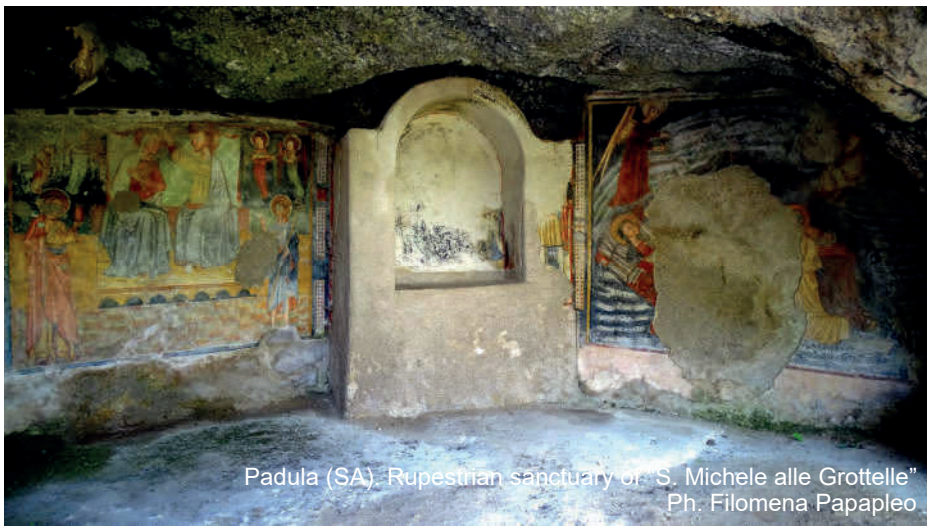
The miracle of St. Michael in Chonae – Russian icon of the 15th century
Public Domain, https://commons.wikimedia.org/w/index.php?curid=1237378



Caselle in Pittari (SA). bas-reliefs representing the Archangel situate on the left wall of the altar in the Cave of St. Michael. Ph. Filomena Papapleo

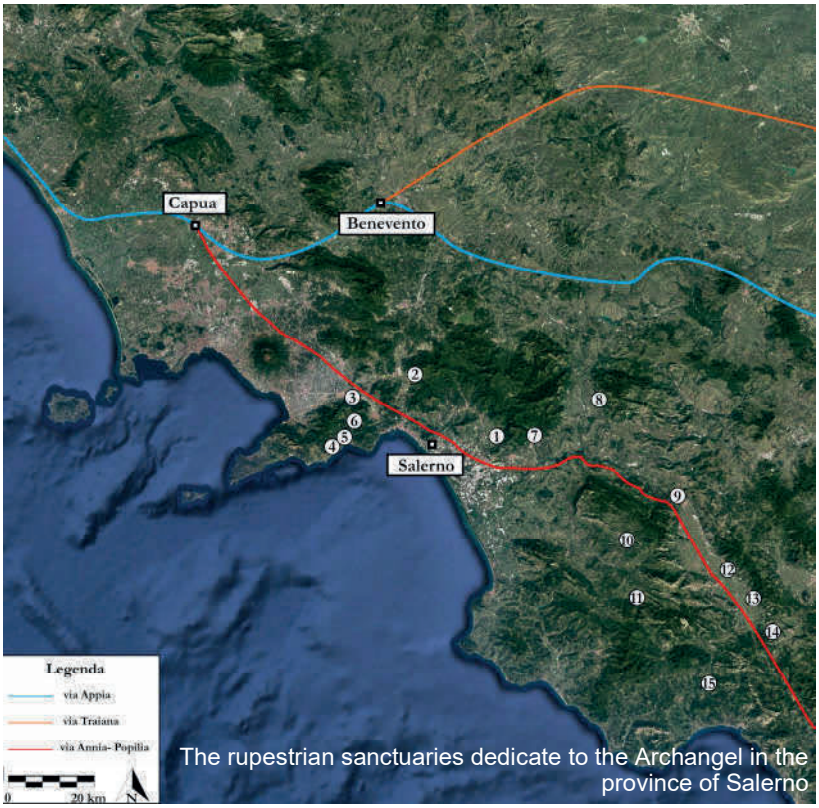
The use of natural caves as a sacred space represent a common practice in different cultures and times. In pagan cultures, the cave was considered a place of birth and refuge, metaphor of the mother's womb as a place of transition from one dimension to another. During the Middle Ages, in particular in the Christian symbolism, caves start to play a different role, representing the cradle of contemplative life. This natural space is strictly connected to the monastic concept of *desertum*, the place where the geographical reality is the easier way to get closer to God, isolating the hermit from the pleasures of the worldly life. Not by chance the fathers of Eastern monasticism are called "Desert Fathers", because of the narrow and inhospitable environments, mainly located in Egypt and Syria, where they developed the first forms of asceticism and cenobitic life. The Byzantine Syria, in particular, represents one of the main models for the diffusion of religious practices inside natural caves during the early medieval period. The karst nature of the place, rich in clefts and grottos, favoured the occupation of this area for cultural purposes, with the spread of churches, monasteries and different hermitic forms (hermits in the desert, caverns, recluses, stylites), located at the edge of the villages from the 4th century AD[1]. Those Eastern models found application in the West thanks to diffusion of Italian-Greek monasticism. Italian-Greek monks, in fact, sought, especially in the southern part of Italy, those same environments that characterized the first hermitic forms and elected cavities as the ideal spatial solution to join to the separation from the world observed in the oldest Christian tradition. Since the 6th century AD, the cave binds to specific devotional forms linked to the figure of the Archangel Michael and his apotropaic and psychagogical features. The Michaelic cult, developed in the Middle East almost at the same time of the birth of anacoretic monasticism, finds space and diffusion by virtue of the rocky environment. The cave, symbol of the abandonment of worldliness in favour of a life of restraint, was seen as the only place where the detachment from worldly good was guaranteed. Moreover, it was also a place of exaltation of the healing virtues of the Saint, lined up in the front row against all the forms of evil, natural disasters and lethal diseases included. Besides, underground caves presents a double meaning: beyond what has already been said, they represent a way out for the diabolical entities hindered only by the intervention of the Archangel. Water and rocks, thanks to the influence of Michael, become the instruments which allow the humankind to preserve the world from the power of the Evil One[2]. The cult of the Archangel reached the Occident on the Byzantine ships. From Monte Sant'Angelo in Apulia[3], the worship spread like wildfire in the rest of Southern Italy through the impetus of the Lombards. The sanctuary of Monte Sant'Angelo, in fact, became a destination for pilgrimages from different part of Europe between the 6th and 7th centuries AD, as is proven by the presence of inscriptions in runic alphabet. It provided inspiration for the creation of other sanctuaries, called *ad instar Garganì*, in Italy and Europe[4]. The Michaelic devotion affected in particular the terri-



Padula (SA). Rupestrian sanctuary of "S. Michele alle Grottelle" Ph. Filomena Papapleo

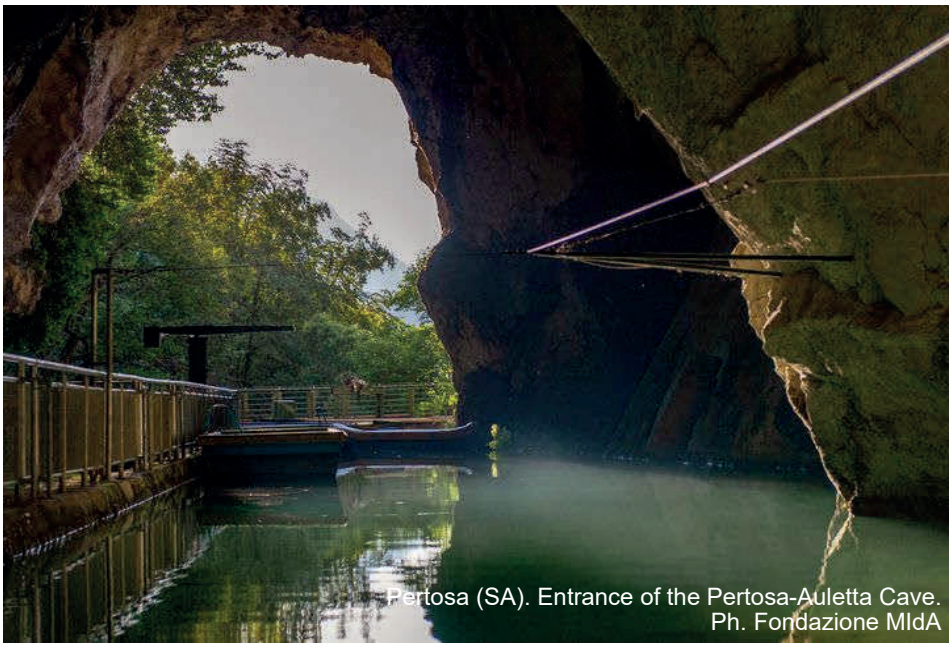
[1]Falcioni 2013, pp. 167-169.
[2]Silvestrini 2014.
[3]A more detailed discussion of the Michaelic cave of Monte Gargano can be found in Giorgio Otranto.
[4]Spiezia 2006, p. 83; Waldispühl 2020, pp. 137-138.

tory of Campania and the province of Salerno that, due to the presence of numerous natural cavities, was enriched by dedications to the Angel between the 6th and 9th centuries AD. The Lombard presence achieved its own high level between Salerno and Benevento and gave a great impulse to the diffusion of the cult of the Saint turning this area into an important pilgrimage destination. According to the distribution of the Michaelic dedication in this region, the area most affected by the presence of hermitages dedicated to the Archangel is the province of Salerno. Here you can find 16 sites linked to Saint Michael distributed along the coastal strip and in the Southeastern hinterland. What can be deduced from analysing their position is the worship is equally distributed both in territories traditionally under Byzantine rule – the Amalfi Coast – and in those directly dependent on the Lombard Princes of Salerno. In the Lombard area, in particular, it is possible to assist to the development of the rocky sanctuary built on the *Mons Aureus*, which, over the centuries, became the object of fervent pilgrimage increasing its importance throughout the territory of Southern Italy. The Michaelic sanctuaries are settled mainly nearby important Roman roads, such as the Via Annia-Popilia and the Via Traiana. This characteristic underlines the existence of devotional paths connected to the Gargano area and to the so-called *Sacra Langobardorum*, along with local routes marked by the times of the agro-pastoral world. In addition to the well-known sanctuary of Olevano sul Tusciano, whose fame is testified by the *Itinerarium Bernardi Monachi*[5], important natural cavities dedicated to the Angel can be found in Fisciano, Nocera Inferiore, Atrani, Ravello, Tramonti, Campagna, Valva, Sant'Angelo a Fasanella, Sala Consilina, Padula, Pertosa-Auletta, Montesano sulla Marcellana, Valle dell'Angelo e Caselle in Pittari. The foundations concentrated along the coast or near the sanctuary of Olevano are dated between the 9th and the 11th centuries AD, in connection with the period of diffusion of Italian-Greek monastic practices and following the fame acquired by *Mons Aureus*[6]. The *Michaelia* risen in the Cilento hinterland and in the Tanagro



The rupestrian sanctuaries dedicate to the Archangel in the province of Salerno

1. Olevano sul Tusciano – Rocky sanctuary of St. Michael. 2. S. Michele di Mezzo in Carpineto (Fisciano) – Cave of "S. Michele di Mezzo". 3. Nocera Inferiore – Rocky sanctuary of "S. Angelo in Grotta". 4. Atrani – Cave of St. Michael. 5. Ravello – Rocky sanctuary of "S. Angelo dell'Ospedale". 6. Gete (Tramonti) – Rocky sanctuary of St. Angelo. 7. Campagna – Cave of St. Angelo. 8. Valva – Cave of St. Michael. 9. Pertosa-Auletta Caves. 10. Sant'Angelo a Fasanella - Rocky sanctuary of St.Michael. 11. Valle dell'Angelo – Cave of the Archangel Michael. 12. Sala Consilina – Cave of St. Michael. 14. Padula – Rocky sanctuary of "S. Michele alle Grottelle". 15. Montesano sulla Marcellana – Cave of the Angel. 16. Caselle in Pittari – Cave of the Angel and Cave of St. Michael.


Pertosa (SA). Entrance of the Pertosa-Auletta Cave. Ph. Fondazione MIdA

[5]This is a report attributed to Bernardo, a frankish monk lived in the 9th century, where the *Michaelion* of Olevano sul Tusciano appears among the most renowned *loca sanctorum* of the Christianity, alongside the Michaelic sanctuary of Monte Sant'Angelo.
[6]For further information, please refer to Di Muro 2019 and Di Muro, Hodges 2019.
[7]Also San Michele alle Grottelle, the only example among the Michaelic caves of the Vallo di Diano was interested by a sort of monumentalization, in a first phase of frequentation had a structure more similar to that of the other caverns.

Valley, instead, going back to the 6th and the 8th century AD. In particular, in the Tanagro Valley this kind of worship seems to conform to the specific model of the sanctuaries *ad instar Gargani*. To characterize the Michaelic sanctuaries of this area – that are *the Grotta di Sant'Angelo* in Sala Consilina, the *Eremo di San Michele alle Grottelle* in Padula, the *Grotta dell'Angelo* in Montesano sulla Marcellana and the karst complex of the Pertosa-Auletta Caves – is the presence in the early stages of their frequentation, of devotional paths linked to the practice of transhumance and dedicated to the lower classes of the local population. The local character of the cult is manifested in the poor monumentalization, determined by specific ideological and environmental needs and by lack of a specific architectonic drive, as a result of the interest of secular or ecclesiastical patronage[7]. The deeply entrenched Italian-Greek presence in this area provides significant added value to the devotional practices still witnessed today in the celebrations held in June, legacy of an oriental tradition. The decentralisation of this area over the Lombard's centre of power, in fact, allowed and favoured the peaceful coexistence of different cultures, whose union originated new and original traditions and habits. Compared to the regional tradition distributed in other parts of the Campania, in which the Archangel Michael turns in an "exorcist", the Saint worshipped in the ancient *Vallis Rationis* seems to lack of these specific attributes, sheltering in a more intimate and arcadic dimension. The Archangel is also associated to other Saints, such as Saint James, which allowed to look at Michael as a pilgrim. The Archangel Michael thus comes to embody the figures of the shepherd and, even more, of the *viator*, personifying the economic vocation of an entire territory, place of exchange of goods, populations, ideas and customs.

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# HUMANKIND AND CAVES IN PREHISTORY
## A MEDITERRANEAN PERSPECTIVE

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Skeletal remains found in a prehistoric burial ground in Grotta Bel (Umbria, Italy)
Ph. Felice Larocca

Whoever has been interested in the most remote period of human history, Prehistory, will certainly have been able to observe how a substantial part of our knowledge derives from discoveries and finds made in caves and caverns. These places, due to their peculiar function of natural *containers* and sedimentary *traps*, often reveal themselves as precious archives of our most distant past. Actually, man, since his first steps in the environment that surrounded him, has repeatedly confronted himself with the underground world, establishing more or less close relationships with it, connected to his needs – material and, soon, also spiritual – more immediate and indispensable.

Prehistoric caves and rock shelters on Taigeto mountain range (Greece)
Ph. Felice Larocca

The more than twenty countries bordering the Mediterranean basin all host, in very different quantities, natural underground phenomena that have accommodated human frequentations from prehistoric times. There is no certain assessment of the quantitative consistency of “prehistoric” caves and caverns in any of them. An estimate in this sense, of course, varies from place to place and is affected by several variables. However, we could believe that, at least in the countries of the western Mediterranean (for which we have more precise data), about one tenth of the caves known today retain deposits bearing traces of ancient human occupations. A concrete example can be that of the Italian Peninsula with its islands: out of a total of about 34,000 known caves, almost 3,500 retain evidence of ancient human presences inside them.

Caves, caverns and rock shelters are the usual places of prehistoric frequentations: types of cavities that see their common denominator in the horizontal development of their respective spaces. Only in rare cases vertical natural cavities have lent themselves to be frequented by man.

The belief that the caves were "the first homes of men" has found great success in all areas of the Mediterranean; it is also true, however, that it was only the underground sectors close to the entrances, the so-called “antecaves”, which allowed advantageous human settlements of a *residential* type. The “antecaves” represent, in fact, the transition area between the surface and the underground, characterized by non-drastic transformation features of the fundamental peculiarities of each of the two "worlds": here the humidity of the underground is attenuated, the temperature is in equilibrium

between the *inside* and the *outside*, the penumbra often forms the link between daylight and interior darkness. In the circum-Mediterranean countries, the settlement pattern for residential purposes, close to the entrances, is recurrent and statistically preponderant: prehistoric man, except in rare cases, has never used the inner spaces of natural cavities for housing reasons. Everywhere the “antecaves”, together with the caves and rock shelters, have offered advantageous possibilities of settlement, often requiring – as was the case on the surface – the creation of structures such as huts and shelters made with wood, branches and leathers (to counter water dripping or wind). Remains of hearths, leftovers from meals, various types of utensils (in stone, bone, ceramic and, later, also in metal), represent tangible evidence of human occupations that at times were occasional, at other times, however, so durable in time to become permanent.

The progressive accumulation of residues due to human activities, sedimentation caused by wind and other reasons, sometimes the collapse of parts of the same cavities, are the cause of the formation of stratigraphies which in some cases can reach several tens of meters in thickness. Often, visiting a prehistoric site, we do not realize that we are walking under the vault of the cave, the same vault that once must have been very far from the walking surfaces used by the ancient visitors of the place: under our feet, in fact, dozens and dozens of paleo-soils used at different times by different human groups are spread, one on top of the other like leaves of a book.

It is to be assumed that there must have been a very close relationship between the full mastery of the use of fire and the "conquest" of the most remote sectors of the caves, those furthest from the surface. It is probable that man only went deeper when he acquired an uncommon skill in manipulating, transporting, dousing and, above all, self-producing fire. The full control of the fire provided humans, in addition to light, also (and above all) a psychological insurance for the return to the surface, if they had experienced accidental episodes of extinguishing the lighting systems used (resinous wood

A mighty archaeological stratigraphy in a cave on Mount Carmel (Israel)
Ph. Felice Larocca

An exceptional prehistoric work of art: a *Bos primigenius* engraved on limestone, from the Grotta del Romito (Calabria, Italy)
Ph. Felice Larocca

Archaeological excavation in the prehistoric site of Grotta della Monaca (Calabria, Italy)
Ph. Felice Larocca

torches, oil lamps, etc.). The fire, illuminating the underground darkness, allowed the taking possession of a "territory" at first unknown, different from the external one, static and almost unreal due to the silence that dominated it. The full control of fire opened a path dense of further possibilities: that of exploiting the advantages and resources that could derive from that same *territory*. And here the most hidden districts of the underground cavities were used as burial areas (sometimes single, sometimes hosting dozens and dozens of burials), as privileged places for the admirable manifestations of the so-called "cave art" (with figurative complexes made mostly with paintings and engravings but, in some cases, even in relief), as spaces dedicated to cults and rituals of various types (connected to beliefs connected to the forces of Nature or to ancestors), as environments from which to obtain resources of various kinds (water, rocks and minerals, etc.). To these uses of the caves we can add many others, mostly widespread according to the territories: not to be overlooked, for example, is the use of underground environments as places of animal shelters, especially in the more advanced stages of the prehistoric age.

Freshwater basin used since prehistoric times for water supply (Laconia, Greece)
Ph. Felice Larocca

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# CAVE BIOGEOGRAFY IN THE MEDITERRANEAN

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Italian cave salamander (*Hydromantes italicus*) found within a cave in Central Apennines.
Ph. Mattia Iannella

The main aim of biogeography is to understand the distribution of life inhabiting our planet in space and time. This discipline is a cornerstone of modern research in subterranean environments because species' occurrences have many implications for assessing and conserving biodiversity. Some species have an important functional role in these environments; for instance, some bats play a pivotal role in caves, transferring organic matter into them (Ghanem and Voigt, 2012); many other species are practically irreplaceable, thus representing keystone species.

Many others are rare and endangered, or they represent taxonomic entities which have few or no living relatives either in surface habitats or in other subterranean habitats.

Despite many studies that have been conducted aiming to improve our knowledge of living organisms in these habitats, much effort is still needed in the future. The difficult access to such environments, in conjunction with the limited number of studies compared to their epigean counterparts (Ficetola et al., 2019), led the researchers to take advantage of some "open windows" in subterranean habitats, such as caves and springs (even though some techniques exist to find species in specific sub-habitats).

In the Mediterranean area, aside from the marine-related caves, the biodiversity found in subterranean habitats shows a latitudinal gradient, reflecting the effect of the past glacial events. In fact, during the Pleistocene glaciations, many species moved southwards (when possible) or became extinct (Hewitt, 2000). As a result, the current subterranean species richness of southern Mediterranean countries is higher than the one measured in the northern ones (Deharveng et al., 2019; Stoch and Galassi, 2010; Zagmajster et al., 2014), even though the karst areas cover many northern European territories (Fig. 1). Moreover, it is important to highlight that some European caves host relict fauna from Tertiary (65 – 15 million years ago); rarely counterparts of such period currently occur in the epigean environments.

Biogeographic research in Europe's cave environments, formally started in 1689 with von Valvasor's discovery of *Proteus anguinus* (described later by Laurenti in 1768), keeps going on since then, for instance, with the advances of the Fauna Europaea (de Jong et al., 2014) or of the PASCALIS project (Gibert and Culver, 2009).

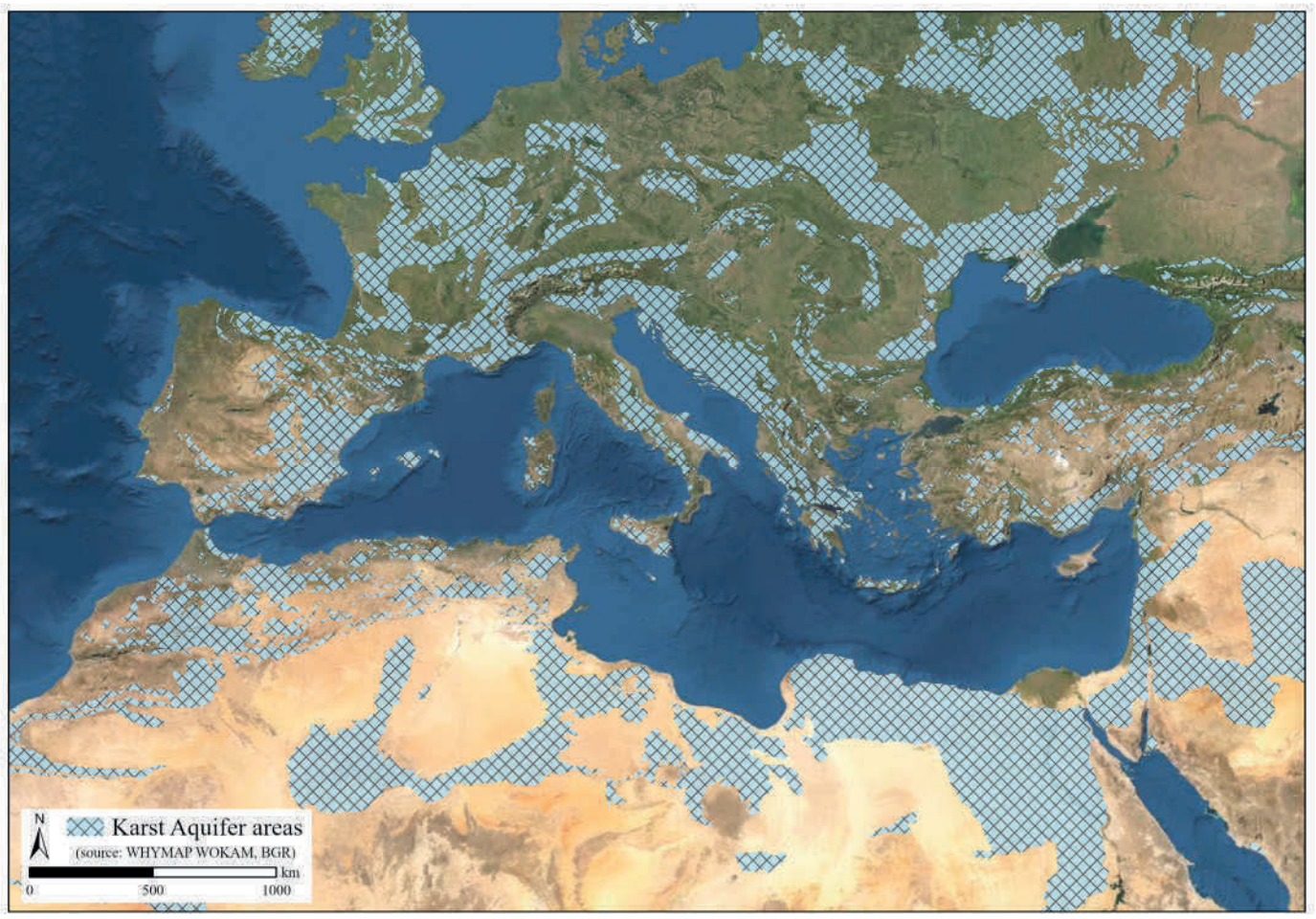


Fig. 1 - Distribution of karst in the Mediterranean area (after Chen et al. 2017), modified).

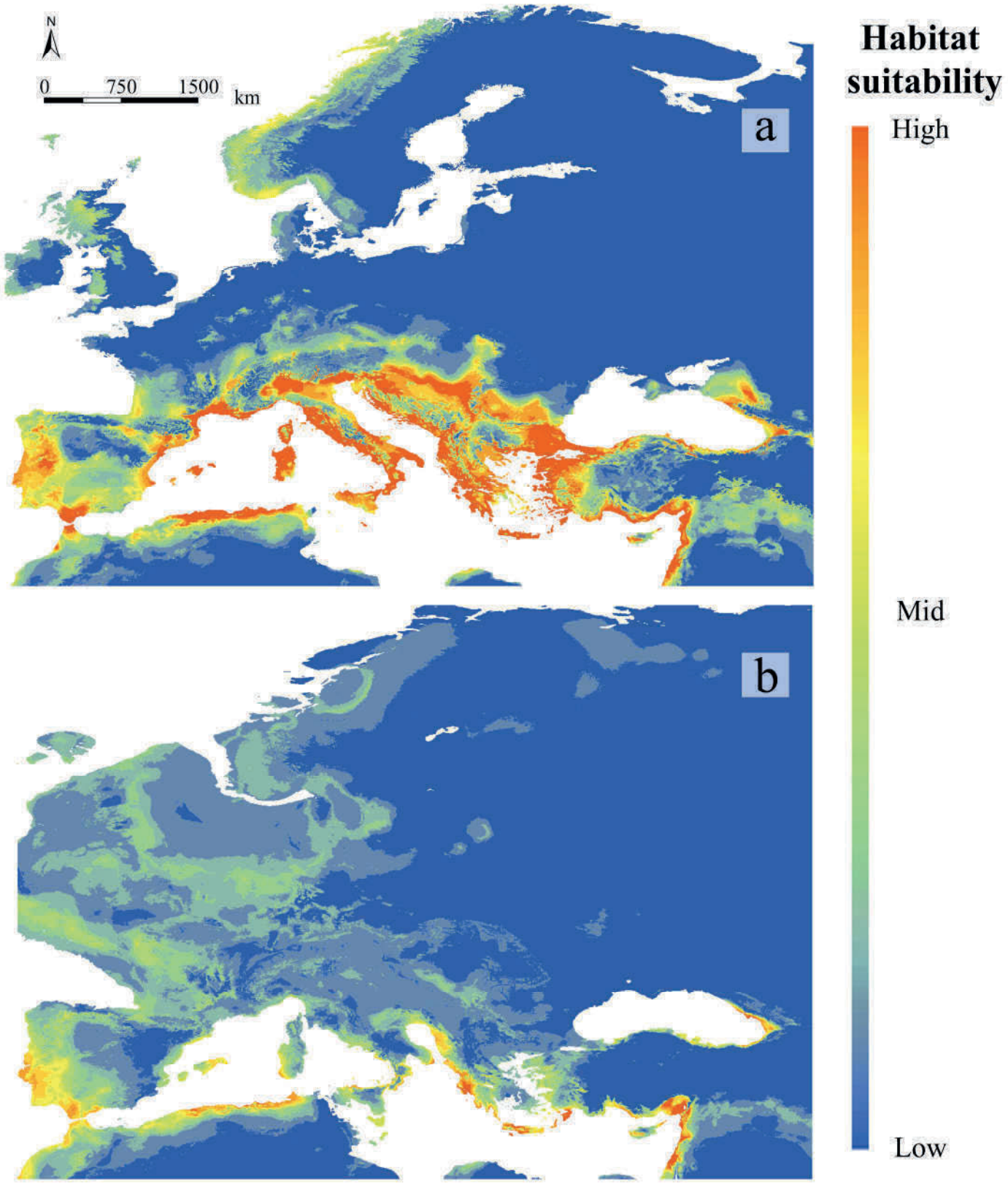


Fig. 2 - Habitat suitability of *Myotis capaccinii* inferred from Ecological Niche Models for current (a) and Last Glacial Maximum (b) climatic conditions (after Di Gregorio et al., 2021, modified).

When referring to life in caves, bats are one of the main group of species that comes to mind. Among many species found in Western Europe, *Myotis capaccinii*, a strictly troglophilous species, shows a pattern of occurrence centered in

the Mediterranean area (Fig. 2a). Recently, Di Gregorio et al. (2021) showed that this distribution is the result of the influence of the Last Glacial Maximum climatic event, which constrained the species towards some coastal climatic refugia in the Mediterranean (Fig. 2b). This finding is in line with the general influence that temperature and precipitation have on the physiology of bats (Ben-Hamo et al., 2013; Park et al., 2000; Salari and Kotsakis, 2011) and with previous studies about the genetic asset of *M. capaccinii* (Nardone, 2015), which also claim that the Mediterranean peninsulas (Iberia, Italy and Balkans, and thus the caves found there) acted as refugia for this species.

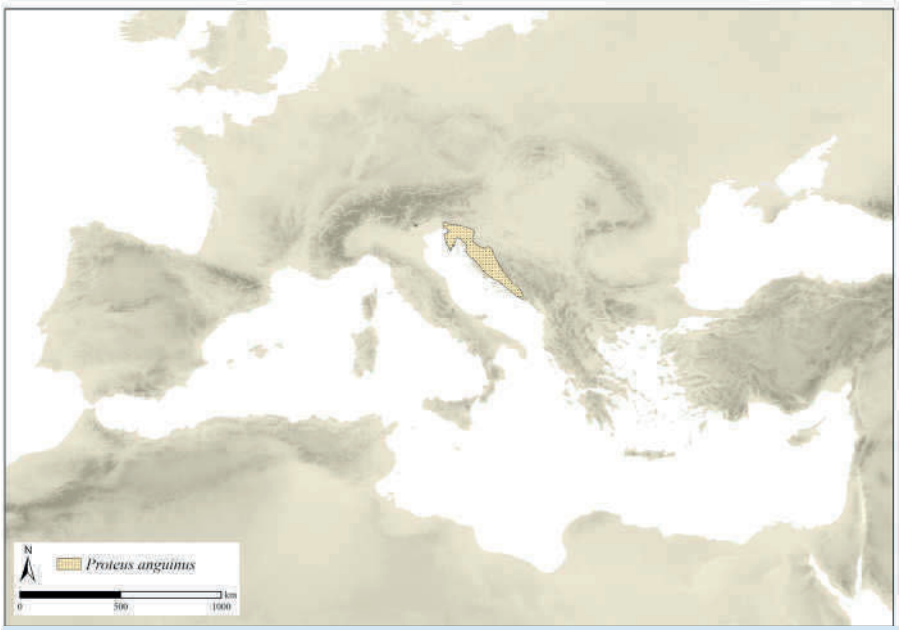


Fig. 3 - *Proteus anguinus* distribution

As far as vertebrate cave fauna is concerned, it is impossible not to mention the Olm (*Proteus anguinus*) and the eight species of European cave salamanders, all belonging to the genus *Hydromantes*. The Olm represents the only stygobitic amphibian found in Europe (Fig. 3), thus having a high conservation value, being considered as "Vulnerable" and with decreasing population trend (Arntzen et al., 2008). The eight *Hydromantes* species also have a high conservation concern, considering that they represent the only Old-World members of the family Plethodontidae (Sparreboom, 2014), together with the Korean *Karsenia koreana* (Min et al., 2005). They mainly occur in Peninsular Italy (even though one of them, *H. strinatii,* also occurs in a small area in France) and in the Sardinia Island.

Despite cave vertebrates overshadowing the invertebrates living in subterranean environments, the latter are by far much more abundant than the former in terms of species richness and ubiquitous in terrestrial and aquatic habitats within the caves (Fig. 4a,b). For instance, many invertebrate species are the only representatives of their own taxon, as ex-

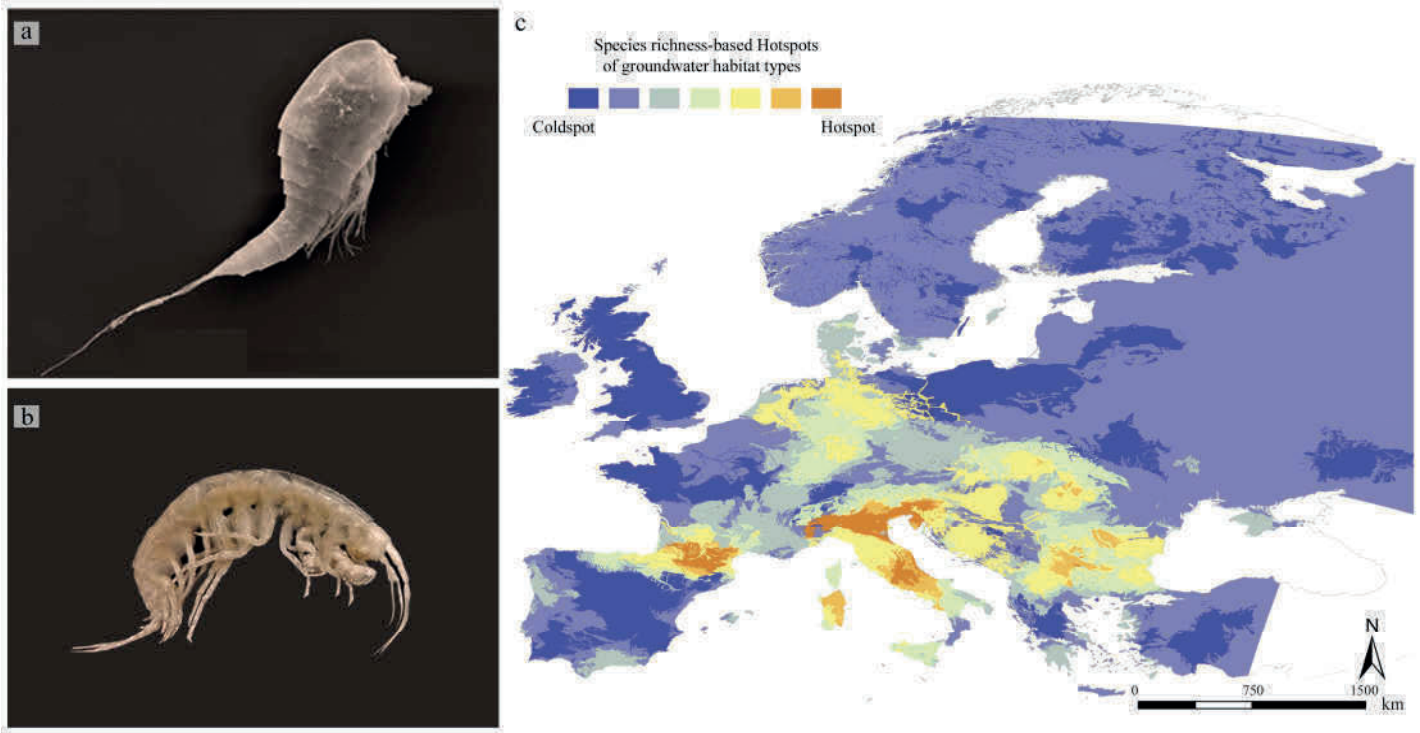


Fig. 4 – a) *Pseudectinosoma sp.* and b) *Niphargus sp.,* two stygobitic genuses (by courtesy of Prof. D.M.P. Galassi, University of L'Aquila); c) European hotspots of species richness, based on the Gi* statistic, inferred from Iannella et al. 2020.

emplified by the cave beetle *Dalyat mirabilis* occurring in south eastern Spain, the Croatian *Eunapius subterraneus* (the only subterranean freshwater sponge in the world), or the Italian small-sized crustacean *Pseudectinosoma kunzi*. This last belongs to the Crustacea Copepoda, a group of minute stygobitic crustaceans inhabiting the groundwater sediments. Due to their holobenthic lifestyle (the whole life cycle is spent among the sediment particles or close to the bedrock in the saturated karst, as well as in the epikarst, thus showing limited dispersal capabilities), they represent useful biogeographic indicators. For this reason, they were selected to identify biodiversity hotspots in Europe: eight areas were found (Iannella et al., 2020), via delineating clusters of subterranean habitat of interest and deserving protection (Fig. 4c).

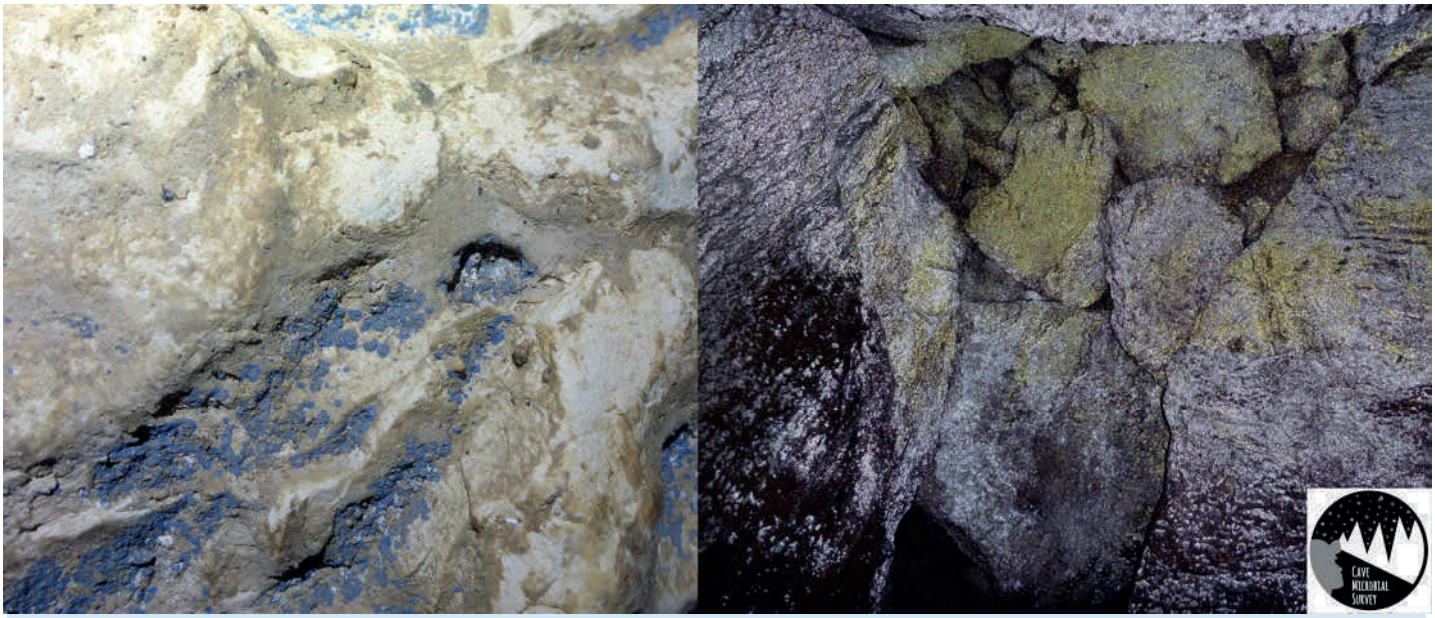


Fig. 5 – Microbial formations in caves
(by courtesy of dr. Ilaria Vaccarelli, Cave Microbial Survey)

Also, troglobitic arthropods, such as the cave beetle *Leptodirus hohenwarthi reticulatus*, have very specific morphological adaptations to caves: this subspecies was the first insect found within a cave, helping scientists to understand how life adapted to the subterranean conditions.

A final mention must be made to some other living forms often more neglected than others when talking about life in caves: microorganisms, such as Bacteria, Archaea or Fungi. By interacting with the substrate on which they live, they actively shape concretions, mineralizing rocks (e.g. Vaccarelli et al. 2021). Also, they represent the basis of caves' food chains (Engel, 2010), with unknown species, potentially representing a resource for the development of biotechnological applications (Tomczyk-Żak and Zielenkiewicz, 2016).

Although they cannot be seen by the naked eye, their activity can be sometimes detected: vermiculations on the ceilings, corrosion residues, unusual colourations or the presence of biofilm adhering to different surfaces are among the phenomena that can be observed in caves (Fig. 5).

Some ongoing projects, such as the Cave Microbial Survey one (a citizen-science program that aims to promote a network on all the microbial signatures in caves) also represent biogeography studies, enhancing the current knowledge on cave microbiology and creating or reinforcing the link among speleological and scientifical activities.

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# MEDITERRANEAN SPELEOBIOLOGY

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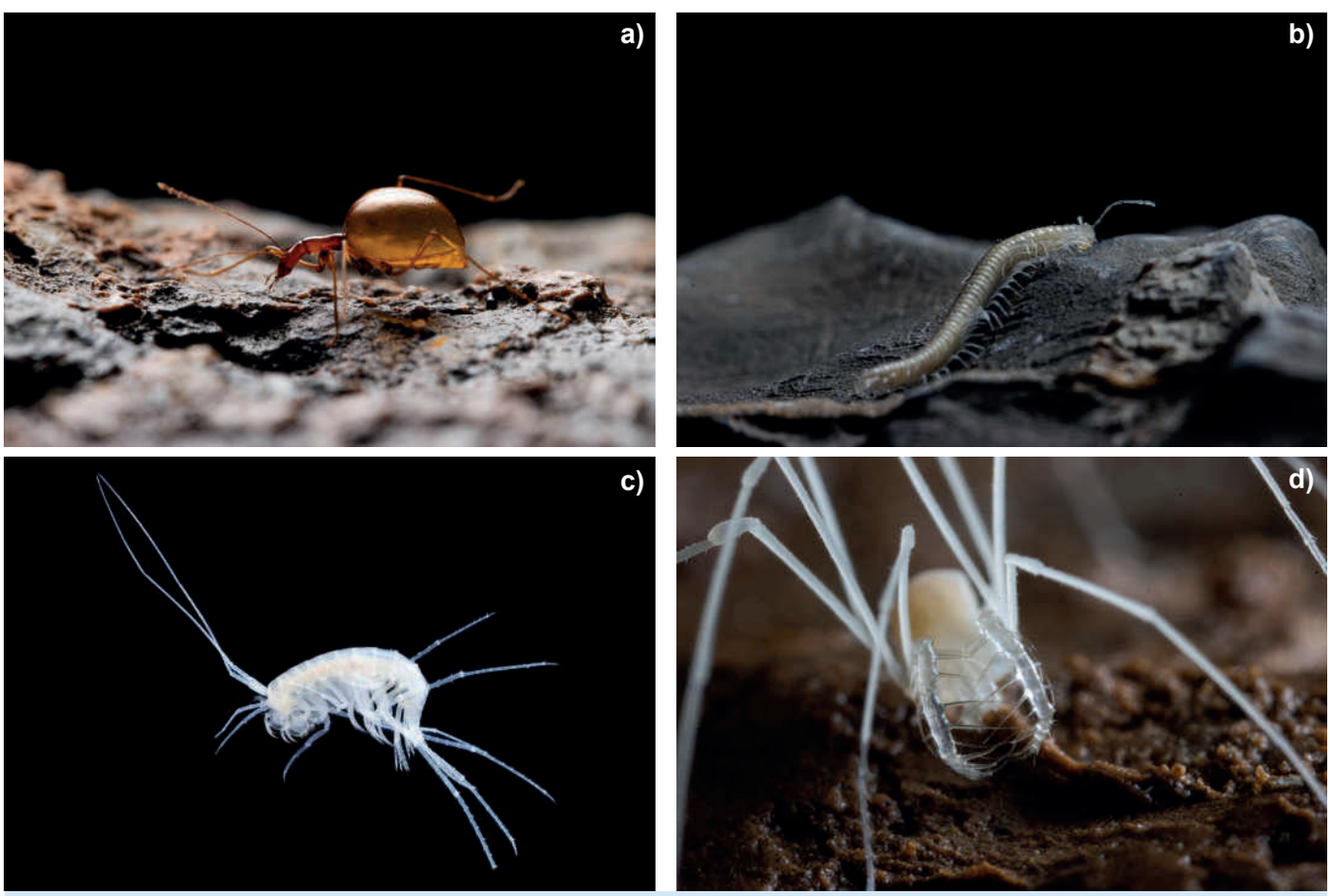
*Neobisium roupa*
Ph. Teo Delić

## UNDERGROUND LIFE AND ECOLOGY OF SUBTERRANEAN HABITATS

Two centuries ago a discovery of a blind beetle with elongated legs and unusual morphology settled a milestone in our perception of life underground. It was until then that people were unaware that life of any form is possible underground. This discovery and the scientific description of the slender-necked beetle, *Leptodirus hochenwartii* Schmidt, 1832, set up a whole new biological discipline *speleobiology*, the biology of subterranean habitats. From the famous tourist cave Postojnska jama in Slovenia, where it was first found, the wave of discoveries of specialized subterranean animals started to spread. At first it set out over the Western Balkan's Dinaric Karst, and was, thereafter, transferred to other mountainous areas in Europe. By the second part of the 19$^{th}$ Century, all larger mountain ranges in Europe, including Pyrenees, Jura, Rhodopes, etc., already had first discoveries of their own, specialized cave-adapted fauna.

Throughout the globe, subterranean animals share similar traits: they lack eyes and pigments, and have elongated antennae and appendages. Morphological changes, often referred to as troglomorphies, most likely developed as an adaptive response to the ecological constraints of subterranean habitats. However, it is not only the caves, where these specialized animals, also known as troglobionts or stygobionts (bound to terrestrial and water habitats, respectively), can be found. They are known from a variety of air or water filled shallow subterranean habitats, including seepage springs, epikarst, hyporheic, scree slopes, soil, etc. The only thing that separates caves from other types of subterranean habitats are their dimensions, enabling us to enter. Different subterranean habitats share the same characteristics. The first and probably the most notable difference, when compared to surface habitats, is the absence of light. Because of this no plant can survive in the subterranean domain. As there is no photosynthesis, the availability of nutrients is reduced. The subterranean habitats are fully dependent on nutrients from the surface, penetrating with sinking rivers, water drips or occasional visitors (bats, crickets, etc.). Both, the temperature and humidity tend to be constant, with humidity kept at a high level. As a result, combined effects of previously mentioned habitat characteristics, sum up in dramatic morphological changes notable in subterranean animals.




Blind and depigmented representatives of specialized subterranean fauna, the so-called troglobionts: a) The first discovered and scientifically described subterranean animal, *Leptodirus hochenwartii*; b) Subterranean diplopod *Haasia stenopodium;* c) A cave amphipod with extremely elongated antennae and appendages, *Niphargus croaticus*, and d) fiercely appearing appendages, pedipalps, forming a death trap in an harvestmen species *Travunia* sp. Ph. Teo Delić

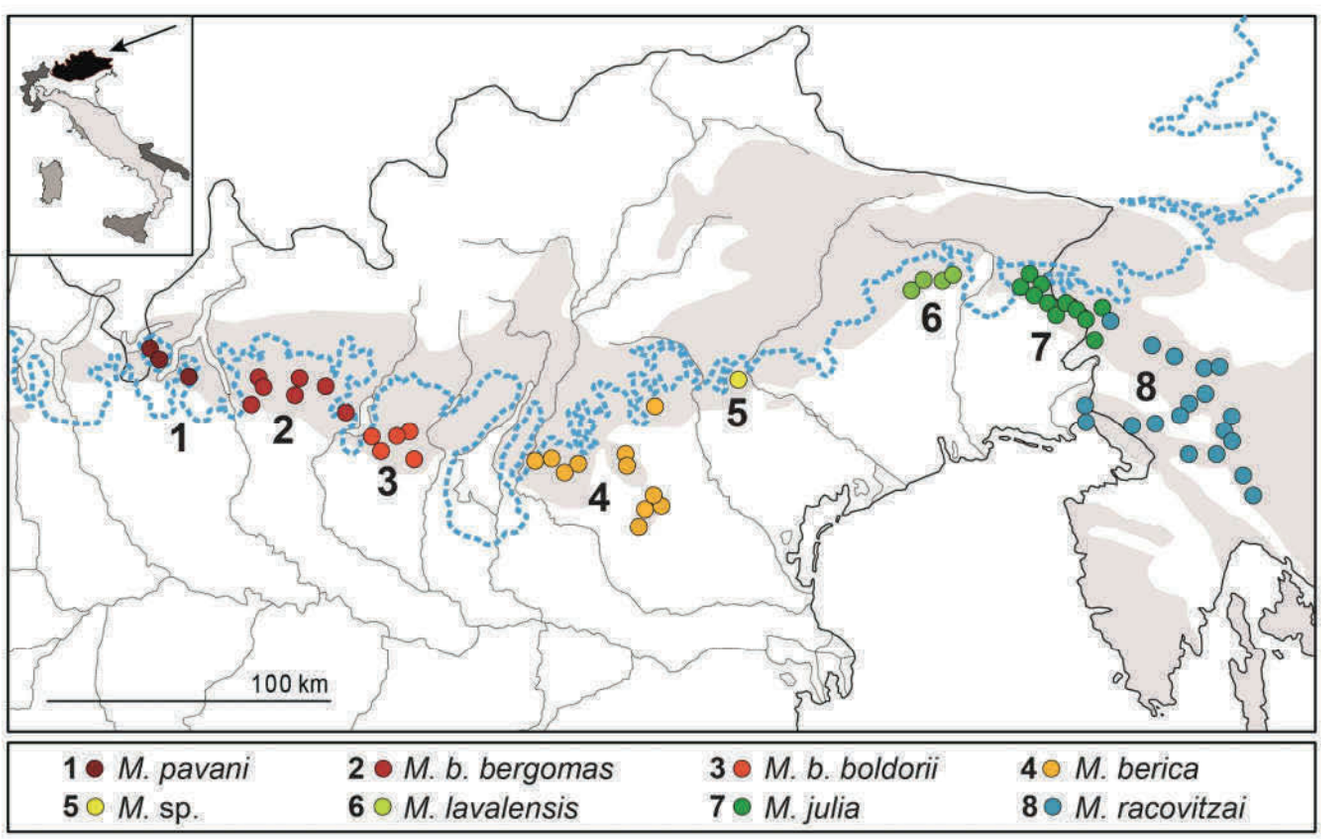
## HOTSPOTS OF SUBTERRANEAN BIODIVERSITY

A large body of data, containing information on species inventories and distributions of troglobionts has been published in the last two centuries. Inclusion of publication records with accurately defined positions of subterranean sites into carefully managed databases, in combination with the usage of computational resources, revealed the spatial patterns present in European subterranean fauna. Due to prevailing characteristic of subterranean domain, its invisibility, the patterns became known much later when compared to surface biodiversity patterns. Once established, they enabled setting the hypotheses and testing the possible mechanism and processes behind the eye catching patterns.

Compared to other continents, Europe bears the richest subterranean fauna. More than half of the global hotspots of subterranean biodiversity, defined by either 25 troglobionts or stygobionts, are found in Europe. One can easily attribute this discrepancy to the relatively long tradition of subterranean research in Europe. However, it seems that for some groups (subterranean beetles, amphipods, springtails), despite additional research efforts in other continents, Europe remains the richest continent. The pattern remains the same also due to the fact that the new species, even genera, are being described not only from unexplored, but also from well explored and biodiversity rich karst areas, i.e Dinarides, Pyrenees or Italian Prealps.

On the continental scale, the difference in species richness is notable. Obvious patterns demonstrate that the number of subterranean species declines northwards and southwards from the so-called “mid latitude biodiversity ridge”, comprising a system of North Mediterranean mountainous chains - Pyrenees, Alps and Dinarides. These mountainous regions bear the highest concentration of subterranean biodiversity hotspots in the world. The reasons for establishment of the “ridge” are manifold, and are largely driven by three environmental factor classes, packed within energy, heterogeneity and history. They include a wide variety of factors like temperature, precipitation, number and size of caves in the area, availability and connectivity of karst landscapes, historical climatic and paleogeographic events.

Probably one of the best documented and vividly imaginable factors, which largely contributed to the existing patterns, are Pleistocene climatic oscillations (2.58 - 0.01 Ma) and Last Glacial Maximum (21,000 years ago). Temperature decline and glacier coverage, associated with permafrost, which extended as far as to the southern Alpine valleys, decimat-




The extent of Last Glacial Maximum, approximately 21,000 years ago, limited the distribution of many subterranean taxa, including subterranean freshwater isopod genus *Monolistra,* to the areas south of Alps. Redrawn from *Stoch & Galassi, 2010* (Still have to get copyright, in process).

ed subterranean fauna north of the Alps.

Zooming in the specific area exposes sub-patterns that can largely differ from the general ones, revealing the existence of hotspots within the hotspots. In the case of the Dinaric Karst, the analysis of species richness in subterranean beetles and amphipods exposed the existence of the two embodied peaks of species richness. One in the northern part of the region, spreading in southern Slovenia, and the other one in the south, in southeastern Herzegovina, Dalmatia and western Montenegro. A relatively large share of subterranean amphipods and beetles in Dinarides, 23 and 31 percent, respectively, are the so-called single site endemics. Known from a single locality only, they are the real, narrowly distributed endemics.

## EVOLUTION (SPECIATION) IN THE MEDITERRANEAN KARST AREA

A large mark on the subterranean fauna of the Mediterranean area was left by the paleogeographic events in the wider Mediterranean region. The whole region itself has a rather complicated history, which is in more detail described in the "Geomorphology of the Mediterranean area" section. For someone who is not familiar with the paleogeographic history of Europe, it is essential to understand that, historically, the continent functioned as a group of islands bound to the tectonic plates. In addition, nowadays mountain ranges were, back in the time, largely shallow seas with lagoons, similar to those that can be found in the tropics. Depending on the movement of the tectonic plates, their interactions triggered raising of mountainous ranges in the north of Mediterranean or disintegration of the existing lands, seas or continental lakes. Such events are well documented in geology or geography, but can be tracked down even in the natural histories of subterranean animals.

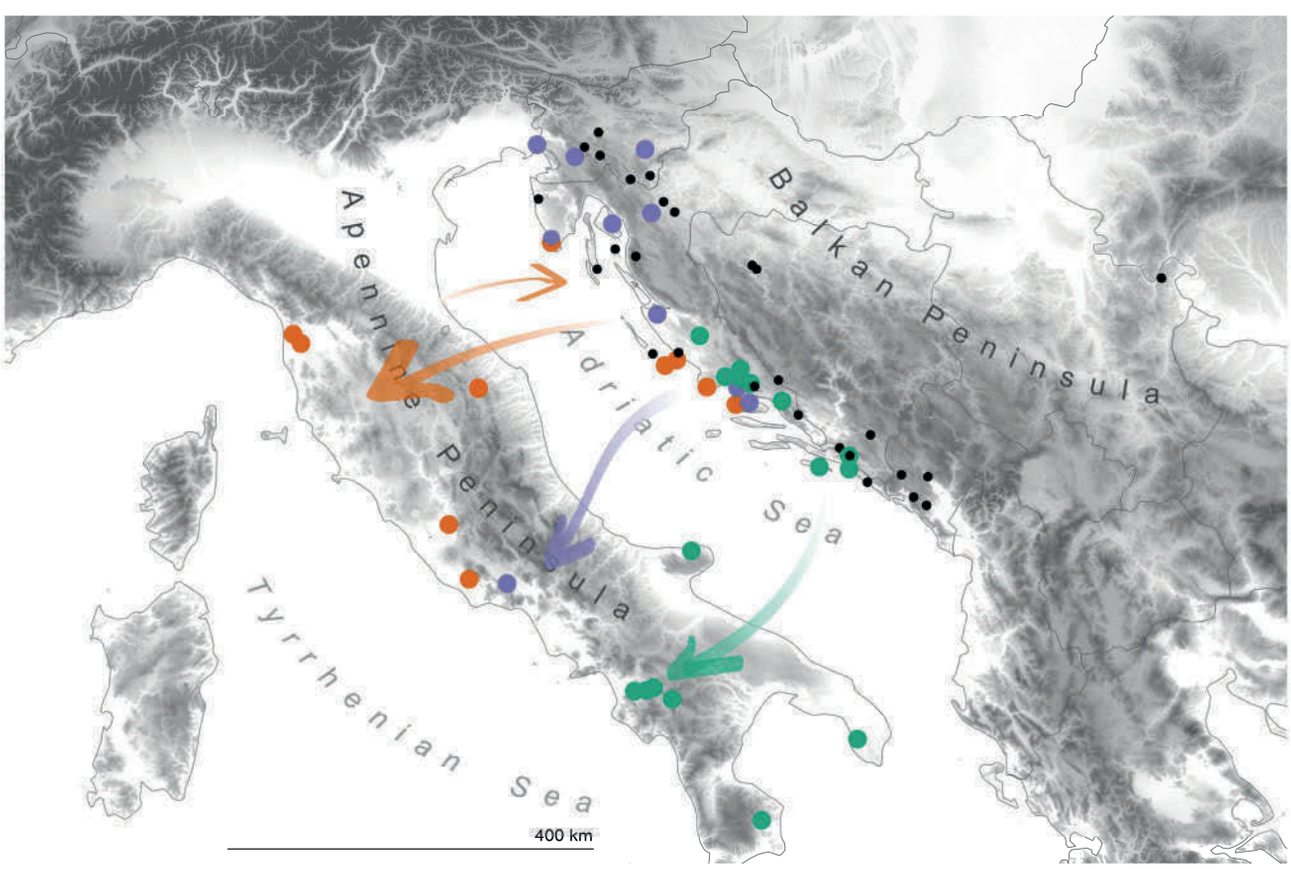
Some of the most remarkable subterranean species from the Dinaric Karst represent the only subterranean representatives of otherwise marine, freshwater or historically widespread freshwater taxa: I an II) The only subterranean representatives of predominantly marine polychetes and cnidarians, cave serpulid *Marifugia cavatica* and cave cnidarian *Velkov-*


Paleogeographical changes largely affected natural histories of many subterranean taxa, including: a) the only subterranean freshwater clam, genus *Congeria*, and the only subterranean freshwater serpulid, *Marifugia cavatica*; b) representatives of collembolan genus *Verhoeffiella*, distributed in remote karst areas throughout Europe (Jakupica, Dinarides, Prealps, southern Catalonia and Cordillera Cantabrica); c) continental radiation of subterranean trechini beetles (photo of *Velebitaphaenops giganteus*) and, d) freshwater isopod genus *Monolistra.* Ph. Teo Delić

*rhia enigmatica;* III) the only known subterranean clams, three closely related *Congeria* species (*C. kusceri*, *C. jalzici* and *C. mulaomerovici*), whose relatives were widespread in surface freshwaters during the Miocene (23.03 - 5.33 Ma); IV) the only subterranean sponge in the world, *Eunapius subterraneus*, and V) the top predator in the Dinaric caves and the only true subterranean vertebrate in Europe, the proteus, "humanfish" or olm, *Proteus anguinus*. Natural histories of these unique taxa, including their distributions and habitats, were largely affected by the paleographic changes in Mediterranean area.

Both, terrestrial and aquatic subterranean taxa, were largely affected by desiccation of the Mediterranean Sea during the so-called Messinian Salinity Crisis (MSC, 5.96 - 5.33 Ma), triggered by the closure of Gibraltar strait. Temporal connection between the European and African land masses enabled exchange of some faunal elements, including some of the subterranean diplopods and trechini beetles, nowadays present in North Africa and the Pyrenees. Presumably, the MSC triggered proliferation in some of the most species richest terrestrial subterranean genera, including beetle genus *Duvalius* and the springtail genus *Verhoeffiella/Heteromurus.* In aquatic subterranean fauna, desiccation of the Adriatic Sea enabled at least two crustacean groups, amphipods (genus *Niphargus)* and isopods (genus *Monolistra)*, to disperse over otherwise impermeable barrier, sea. Most of the dispersal pathways led from the Dinarides to the Apennines, however, the vice versa events were also enabled. An imprint of these events can be noted even in ecological preferences of closely related sister species of "transadriatic" crustaceans, distributed on the opposite sides of the Adriatic Sea, persist or well tolerate brackish waters. In addition, regression and transgression cycles caused establishment of special types of caves, the so-called anchialine caves. Such caves are found all around the Mediterranean Sea. They are characterized by the existence of salinity clines, caused by the input of freshwater into otherwise marine cave environments, and are distinguished by their specialized and highly endemic fauna.

Although most of the presented patterns and processes were connected to origins of subterranean life through physical




Desiccation of the Mediterranean Sea, including the Adriatic Sea, during Messinian Salinity Crisis (5.96 – 5.33 Ma) enabled establishment of dispersal pathways over temporal land-bridges connecting the Dinarides (Balkan Peninsula) and Apennine Peninsula (and vice versa). The major pathways of the three major clades of "transadriatic" representatives of the subterranean freshwater genus *Niphargus* are represented in orange, purple and green (redrawn from Delić et al. 2020)

changes in environments, this is, by far, not the only way that natural histories of subterranean animals are affected. A large part of these highly specialized taxa originated through the processes of ecological speciation, implying differential use of environmental resources, changes in behavior connected to predator avoidance, etc. Some of probably most demonstrative cases of ecological speciation in caves include species rich communities of closely related subterranean amphipods of the genus *Niphargus* or highly specialized filter-feeding, the so-called hygropetricolous beetles. Unfortunately, due to repetitive historical oversimplification of subterranean habitats, the ecological aspect of speciation in the subterranean domain has been neglected for years. However, with the raising awareness that the processes operating in the subterranean domain are identical to the ones operating in the surface habitats, we are setting the stage for future challenges and development of ecological studies within the subterranean domain.

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# ALBANIA

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Shpella Shtares, Giglio room
Ph. Archivio GSM | Fabio Semeraro

## GENERAL INFO

Albania has an area of 28,748 km$^2$ and about 25% of the whole country's area is karstic. There are 26 different massifs scattered around the country and their extension is included between 34 km$^2$ of the Kremenara massif (Ionian area) and 1,162 km$^2$ of the Albanian Alps.

The karst types in Albania are mainly:

- High mountain karst;
- Mediterranean karst;

There are also two principal evaporitic massifs, developed into Permian-Triassic evaporites (areas of Korab and Dumre). The smallest area is Kravaja developed into Messinian evaporites.

The earliest known information about the caves in the country is found on a map of the Karaburun peninsula of the 14th century, where two caves are marked. Data on Albanian caves can be found on topographic military maps of Austria, Germany and Italy of the first half of the 20th century. Early information about caves is also present in notes of studies by traveling scientists from several European countries. Among them, there are:

- In Franz Nopcsa's reports written during his numerous geographical and geological studies on the Albanian Alps, 8 caves are listed (Early '900s);
- Franco Cardini, made important prehistoric discoveries in about 60 caves in the south of the country, (between 1930 and 1939);
- Hungarian Hubert Kessler conducted cave research on Male me Gropa's Massif Mali me Gropa (1958);
- American Jack Baer visited several caves in the country (1976).

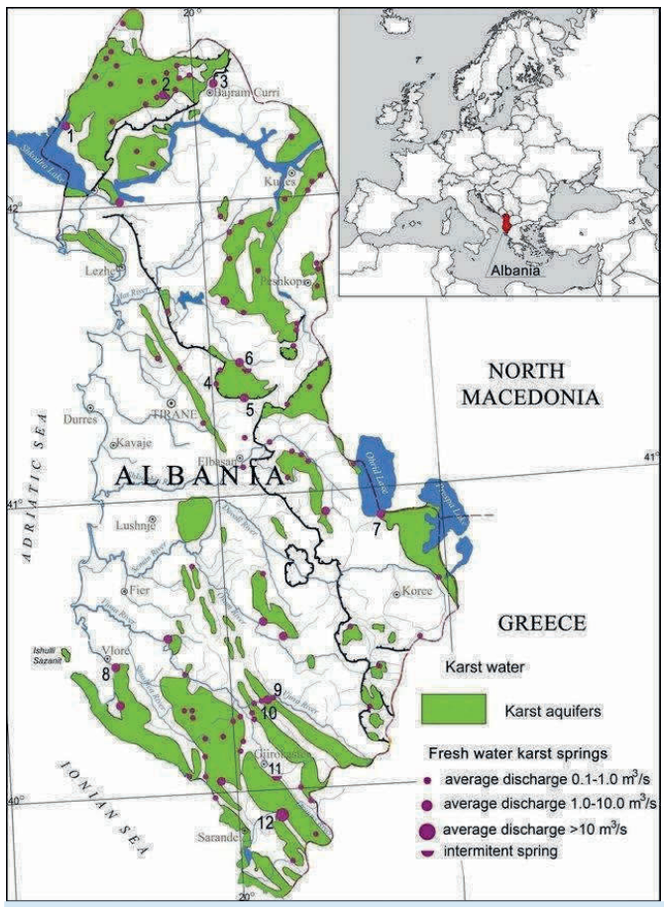



Image by Eftimi et al. (2019). Numbers in the map mark the position of the most important karstic springs: 1) Syri Sheganitt; 2) Gurra Ftohte; 3) Vrella Shoshanit; 4) Selita; 5) St. Maria; 6) Uji Bardhe; 7)Ohrid lake; 8) Uji Ftohte; 9) Black Eye; 10) Kroi Isake; 11) Viroi; 12) Syri i kaltër.

- Gëzim Uruçi founded the Speleological Association of Shkoder in 1971, later he established the National Speleo-Alpine Center of Albania in Shkodra (1991). Shortly after he also founded the Albanian Speleological Society (ASS). However, the ASS is not a member of the Union Internationale de Spéléologie (UIS) and its activity has been suspended for several years.
- Since the mid of '90s several foreign's speleological campaigns have been taking place with the aid of local speleologists and ASS.

## KARST AREAS

Albania's karstified landscape is well developed. The 30 several massifs can be gathered in 6 six tectonic major areas bringing the whole karst surface to 6,725 km$^2$. There are two large areas in the country. The first one is the Ionian area, developed for 2,588 km$^2$ and comprising 4 different massifs. The second one is the zone of the Albanian Alps, in the north of the country. It is not split in subareas and the whole area has an extension of 1,166 km$^2$. Other minor areas such as the Mali me Gropa as well as Mali Dejes represent important areas from the speleological point of view. Recently, due to the presence of several thermal springs, important hypogenic sulfuric caves were discovered in the area of Holtas Canyon (Elbasan prefecture).

Due to the scarcity of local speleologists, the collection of pieces of information of the speleological heritage are not well gathered, instead they are scattered into several speleological bulletins. The systematic research in caves is carried out mainly by foreign cavers, many of which are Europeans.

To date, the longest known cave is Shpella Zezë which has been explored by the Commissione Grotte E. Boegan for

over 20 years. The cave lies on Mali Hekurave (Albanian Alps), in Skodër region, and it develops for over 6 km with a depth of -60/+200 m (Corazzi, 2017). Shpella Shtares, on the Mali e Shtreze (Albanian Alps), is the second longest known cave with a development of over 5 km, mainly sub-horizontal (Pastore et al., 2019). Shpella ne Maya e Arapit, on Mali Arapit, has a development of 3,172 m with a difference in height of +364/-26 (Zhalov, 2015). Syri i Kaltër (or Blue Eye) is the most important Albanian karstic spring and submerged cave. Instead, the only touristic cave is Pëllumbasit (also known as Shpella e Zezë), not far from Tirana.

Shpella Avullit, Elbassan Prefecture, partial development 1851 m - 418 m, hypogenic sulfur cave still under exploration
Ph. Ivano Fabbri, Gruppo Speleologico Faentino

## NUMBER OF REGISTERED CAVES: :-2,000

| Longest caves | |
|---|---|
| **Name** | **Length (m)** |
| Zezë Cave (Black Cave), Hekurave Mountain, Albanian Alps (Tropoja County) | > 6,300 |
| Shtare Cave, Nikaj-Mërtur, Albanian Alps (Tropoja County) | > 5,000 |
| Puci Cave, Albanian Alps (Shkodra County) | > 5,000 |
| Maja e Arapit Cave, Albanian Alps (Shkodra County) | 3,286 |
| Njerëzit e Lagur Cave or the Wet Men Cave, Albanian Alps (Shkodër County) | 2,000 |
| Piro Goshi Cave, Tomor Mountain (Skrapar County) | 1,500 |
| Mark Shytani Cave, Nikaj-Mërtur, Albanian Alps (Tropoja County) | 1,470 |
| Perr Bosh Cave, Nikaj-Mërtur, Albanian Alps (Tropoja County) | 1,350 |
| Ru Cave, Radoima Mountain (Shkodër county) | 1,134 |
| Kolë Gega Cave, Nikaj-Mërtur, Albanian Alps (Tropoja County) | 1,050 |
| Baruti Cave, Tërvol Mountain (Gramsh County) | > 1,000 |
| Kakver Cave, Nikaj-Mërtur, Albanian Alps (Tropoja County) | 1,000 |
| Mërkurthi Cave, Oroshi Mountain (Mirdita Country) | 830 |
| Kabashi Cave, Tërvol Mountain (Gramsh County) | 700 |
| Kusia e Nue Gjonit Cave, Oroshi Mountain (Mirdita Country) | 750 |
| Merkurth Cave, Oroshi Mountain (Mirdita Country) | 472 |
| Mengaj Cave, In Messinian gypsum (Kavaja County) | 280 |
| Akulli Cave (Ice Cave), Albanian Alps (Tropoja County) | 250 |
| Jubani Cave, Sheldi Hill (Shkodër County) | 225 |

| Deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| BB-30 Cave, Bridash Mountain (Shkodër County) | - 610 |
| Shpella Ru, Radoima Mountain (Shkodër County) | - 580 |
| Njerëzit e Lagur Cave, or the Wet Men Cave, Albanian Alps (Shkodër County) | - 520 |
| Celicokave Cave, Bridashit Mountain (Shkodër County) | - 505 |
| Ne Shen Cave, Deja Mountain (Dibër County) | - 450 |
| Maja e Arapit Cave, Albanian Alps (Shkodër County) | - 413 |
| Avullit Well (Steam Well), Tërvol Mountain (Gramsh County) | - 380 |
| Viroi reached (Gjirokastra County) | - 278 |
| Xhek Marku Well, Bridashit Mountain (Shkodër County) | - 234 |
| Sterra Uvlen, Tomor Mountain (Skrapar County) | - 227 |
| Sterra e Kakrukës, Tomor Mountain (Skrapar County) | - 203 |

Shpella Shtares, passage of the Pantheon
Ph. Archivio GSM | Orlando Lacarbonara

## MARINE CAVES : -7

**Brief state-of-the-art of the Marine caves**

The first explorations of marine caves were carried out in 2003 by G. Belmonte (Marine Biology Station - University of Lecce) in collaboration with Apogon association. They launched the speleo-dive research on the central coast of Karaburun peninsula. Several caves were explored, among which:

**The Underwater Cave of the Xhenemi's (Hell's) Gorge.** The Cave lies at the foot of the western slope of the Sazan Island, right in the depths of the Gorge of Xhenem Bay. It also appears in the surface in the inner part of the Island in the form of a deep well, which is yet to be explored. Its entrance is at a depth of 10-12 m. The direction of the cave follows the western slope of the Sazan Island with galleries filled with water. The Cave is invisible from the outside.

**Haxhi Ali Cave.** It is located between the cape of Gjuhza and Gollovec at the northwestern end of the Karaburun peninsula. Until now, it is considered the largest sea cave and the most famous on the Albanian coast. Its entrance, in the form of a dome, directly above the sea is 45 m high. Therefore, you can enter the cave directly from the sea only by a small boat. The entrance corridor is about 40 m long, 20-35 m wide and 5 m deep. Its first part, called the "pool", which resembles a "lake", inside a large dome-shaped hall is about 60 m long and up to 40 m wide. The maximum height of the ceiling, in the form of a dome, is about 18-20 m. Here the depth reaches about 10-11 m. This hall is surrounded by wet rocky slopes, with solid waterfalls and stalactites. On these slopes there are galleries and rooms with fresh water springs. In total, the known part of the cave (hall plus entrance corridor) is about 100 m long. Many indications point to a very large cave, mentioned for the special beauty of stalactites and stalagmites. Dozens of species and rare marine life live in its waters. At its entrance are found ancient fragments of amphorae of the first centuries of our era. It is known as the Cave of Haxhi Ali, who was a well-known 17$^{th}$ century Ulcinj sailor. This cave has been elected as a natural monument.

**Karaburun cave (K1).** It is a cave partly under water. It lies southeast of the coast. The entrance to this cave, up to 15 m below sea level, is hardly distinguishable between several small caves on the shore of the bay. Next to this Cave lies the Great Room under water, about 25 m long. This underwater cave has diverse wildlife: algae, sponges, etc.

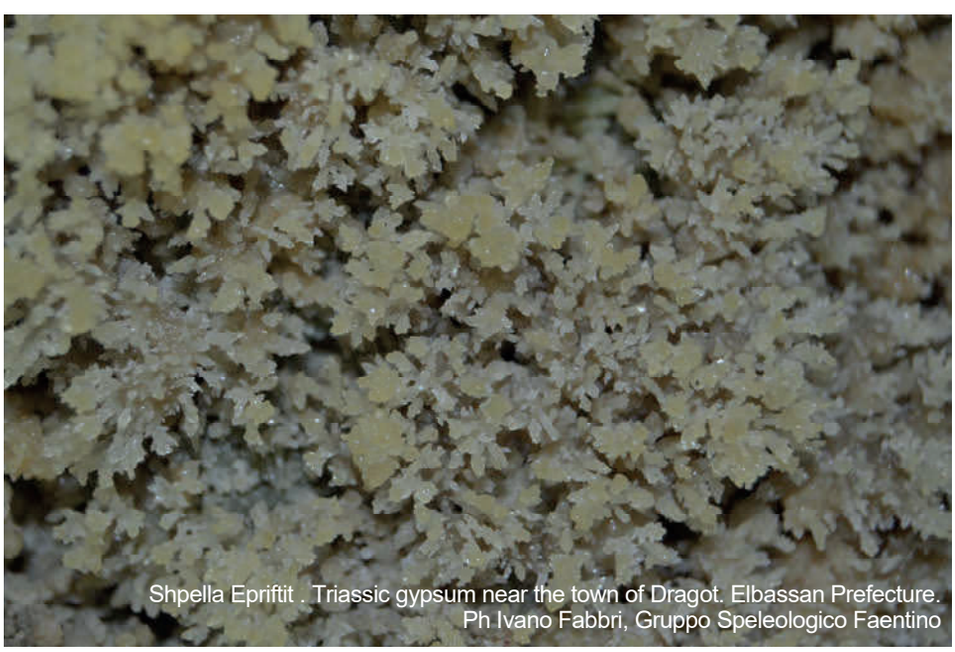
| Most important marine caves | | |
|---|---|---|
| **Name** | **Length m** | **Depth m** |
| Haxhi Ali's Cave, Karaburun peninsula (Vlora County) | >100 | 10-11 |
| The Underwater Cave of the Xhenemi's (Hell's) Gorge in western slope of the Sazan Island (Vlora County) | - | 10-12 |
| Karaburun cave (K1), Karaburun peninsula (Vlora County) | 25 | 6-15 |
| Ilqe peak cave (K2), Karaburun peninsula (Vlora County) | 50 | 8 |
| Nexhajve Cave, Karaburun peninsula (Vlora County) | 50 | 10 |
| TunneL cave (K3), Karaburun peninsula (Vlora County) | 100 | 9-13 |
| Laurel/ Bay Leafe Cave, Karaburun peninsula (Vlora County) | 15 | 10 |

**Ilqe peak cave (K2).** Also known as Bay Boat Cave. It is an underwater cave, located in the radius of Maja Hilqe (731 m), in the southeastern part of the coast, on the shores of the small bay with a depth of 35 m. At a depth of about 8 m, it develops in the form of a tunnel, half submerged under water, about 50 m long and about 3 m wide. This cave is known for its diverse wildlife: algae, sponges, etc.

**Nexhajve Cave.** It is located on the water's edge on the shore of the western slope of Mount Rrëza e Kanalit. There are two entrances, one directly from the sea shore and the other is reached by diving, a few meters into the cave. The first part is covered by sea water, while the second part is about 50 m long, in the form of a very wide and high corridor, inside the rock. Full explorations will be able to determine its actual size.

**Tunnel Cave (K3**). It is located very close to the cave of Majes se Ilqes; in the same bay. It 's half submarine. Its large, half-submerged entrance is reached by boat. Further, the cave is in the form of a semi-submerged tunnel, about 100 m long and 9-13 m deep.

**Dafina Bay Cave.** It is located on the coast of this bay. To enter this cave, you have to swim for about 15 meters. The end of the first part is covered by the sea, while the rest continues on a small sandy beach, behind which lies a very wide and high hall, full of fallen stone blocks.



Shpella Epriftit . Triassic gypsum near the town of Dragot. Elbassan Prefecture.
Ph Ivano Fabbri, Gruppo Speleologico Faentino

## ARTIFICIAL CAVES: N/D

**Brief state-of-the-art in artificial speleology**

There is no accurate information on the artificial caves because most of them were used as military bases during the communist period. Even today there is no official access or data on their number.

Shpella Eremite, archaeological site with rock painting from the Byzantine period. Shebenik-Jabllanica National Park. Elbassan Prefecture. A detail of the fresco on the vault of the cave. Ph Ivano Fabbri, Gruppo Speleologico Faentino

## NATIONAL CAVING ORGANIZATION

There are two Albanian speleological associations:

- Albania Speleological Society (founded in 1991), Shkodër
- Albanian Speleological Didactic Scientific Association (founded in 1992), Tirana.

The Society is not a member of the UIS and its activity has been suspended for several years, while the second continues its activity.

## NUMBER OF SPELEOLOGISTS: ~10

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 1

## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLICATIONS

There are neither National magazines nor main speleological journals.

Fundamental publications are:

- Zhalov Alexey (Editor), Bulgarian Speleological Studies in Albania 1991 – 2013;
- Ziu Trifon (1988), Shpellat karstike të Shqipërisë.

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST

- University of Tirana;
- The Albanian Scientific Speleological Didactic Association.

## BIOSPELEOLOGY

Biospeleological studies in Albania are lacking and scattered and bibliography on the Balkan region biospeleology has few works about this area.

A detailed work about bats is contained in “Bat Populations in Albania: Structure and Dynamic of Populations” (Théou, 2015), where are described the 33 bats species dwelling in Albania. The research was made in 209 caves, 197 former military buildings e 12 mines in the whole Albanian territory, leading to the birth of the “National Database of Bats” and of the “Atlas of bats in Albania” (Théou & Bego, 2018).

Many works are on cave dwelling arthropod and mainly made by foreign research. Yet, these works refer either to individual species or genus, even though there is not a systematic work (Jaksic, 2004).

Regarding Araneidae, 15 species dwelling in Albanian underground sites are known (Deltshev et al., 2011), but Deltshev (2008) remarks that Albania is not well explored.

To date, it is possible to find a systematic work on cave dwelling fauna in “Results of biospeleological studies during the Bulgarian speleological research in Albania (1991-2013)” (Simov in Zhalov, 2015). This work was made in over 30 Albanian caves, and it led to a record 44 taxa of troglobites, troglophiles and trogloxenes; 2 new genera and 10 new species of troglobite isopods, myriapods and beetles were described. Twenty species were recorded in Albania for the first time, whereas for the rest new data on their distribution in Albania were added.

Aquatic subterranean fauna was not systematically collected in caves and the interstitial fauna is almost unknown. Several groups are fully neglected and study of cave fauna of some regions like the internal Albanids is only starting (Juberthie *et al.*, 2012)

According to characteristics of the submerged caves of the Albanian coast there are benthic assemblages which are not common or even absent from the Italian side (Belmonte et al., 2006). A very noticeable one of these is the population of Hypsichomus stichophthalmus (Polychaeta) in the Haxhi Ali cave. In general, also vagile benthos appeared more bundant (fishes, echinoderms, worms, crustaceans) than in Italian caves. From the abiotic point of view, a lower temperature has been measured more than 3 m below the sea level, which probably is mainly responsible for these biotic assemblage differences.

Shpella Zgardamene, archaeological site. Elbassan Prefecture
Ph Ivano Fabbri, Gruppo speleologico Faentino

## LEGAL STATUS OF CAVES AND PROTECTION RULES

The main law which rules the natural caves and karst landscape is the Decision of the Council of Ministers N.451 of 16/09/1993 “On the management of the caves”.

The law rules the access to the cave and establishes caves as national natural heritage. Any speleological group, foreign or local, that want to explore caves in Albania needs an official permit by the Committee of Environmental and Preservation and Protection (CEPP). Foreigners must have a local Albanian speleologist in their research group and also a fee payment to CEPP is mandatory.

Also fundamental is the law N.8906 of 06/06/2002 that declares and rules the management, administration and uses of the protected areas and their natural and biological resources.

Shpella Kabashit, Elbassan prefecture
Ph Ivano Fabbri, Gruppo speleologico Faentino

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# ALGERIA

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Grotte Kaf el Kaous
Ph. Atia Redha

## GENERAL INFO

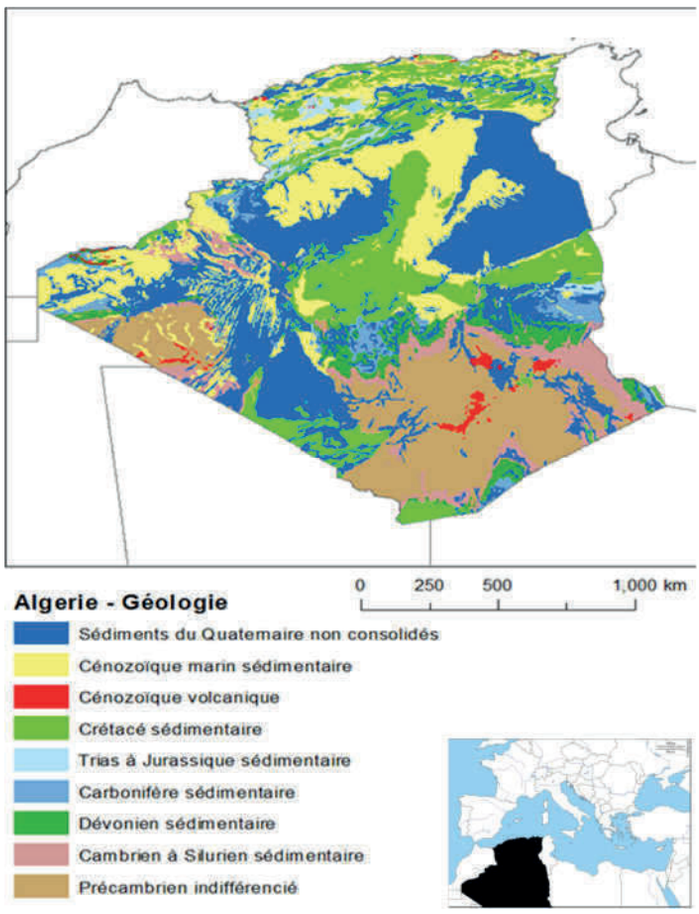
In Algeria (2,234,714 km$^2$), caves have been used by man, for a long time, as refuges, shelters or places of worship. This traditional use of the underground environment continues to the present day, notably in the troglodytic shelters of the Aurès in north-eastern Algeria.

Some caves have particular stories such as the Cervantès cave in the center of the capital where the famous Spanish writer took refuge after his escape, in the 16th century.

Other caves have more ancient stories such as the prehistoric caves of Afalou Bourmel and Gueldaman which bear witness to a human presence dating back to the Paleolithic period.

Underground exploration and speleology began in Algeria at the beginning of the last century under the impulse of French geologists, who were looking for hidden fresh water reserves, and were supported by sports speleologists, thus giving Algerian speleology its first records (Anou Bousouil - 505m, the second largest abyss in the world in 1948, underground Tafna, the longest underground system in Africa, 3.9 km, in 1933)

During the war of liberation, the Guerrillas set up numerous hiding places and refuges and even small hospitals, and the bones of martyrs are regularly found in several caves in the country.




From the beginning of the 1970s, prospecting takes over, led by foreign aid workers, often geologists and hydrogeologists (Quinif, Coiffait, Fabriol, Collignon, etc.). A rich documentation was realized and many Algerian speleologists were trained during this period, the first expeditions start with new results (Anou Boussouil (-805 m), Tafna (17,6 km) and Anou Ifflis (-1,150m). The first Algerian teams were created and organized in the form of associations, in Bejaia, Beni Yenni, Miliana, Boufarik Constantine and Tlemcen). Unfortunately, the discipline remained reserved for a well-to-do and educated elite for several years, but for the last ten years or so there has been a lively revival of interest in mountain sports and a democratization of the practice of speleology on a national scale.

Tamanrasset
Ph. Redha Atia

## KARST AREAS

From a geological point of view, the country is split into two major tectonic units, separated by the South Atlas Accident. The northern part is affected by the alpine tectonics and crossed from west to east by the Saharan Atlas chain in the south and the Tellian Atlas in the north (most of the population and it is also the main area where mountain sports are practised, especially in the Djurdjura, the Babors, Tlemcen, Guelma and the mountains of Saida, Ouarsenis, and the mountains of Tébessa. The southern part, which rests on a Precambrian basement is covered with sediments from the Paleozoic to the Mesozoic (most of the hydrocarbon and groundwater resources). The remoteness of this region from the main urban centers and the aridity of the climate do not favour the practice of speleology activities.

The main karst areas of the country are:

- the tubular massif of the western Tell (Mountains of Saida, Mountains of Tlemcen, Mountain of Daia).
- the "limestone chains" Ouarsenis, Zaccar, Bouzegza, Djurdjura, Arbalou, Babor.
- Connstantine's neretic massif (Fortas, Guerioun, Sidi Ghris .....)
- Saharan Atlas (Djebel Amour, Monts des Ksours, Ouled Nail, Aures).the coastal massifs (Traras, Sahel D'oran, Tenes,...)

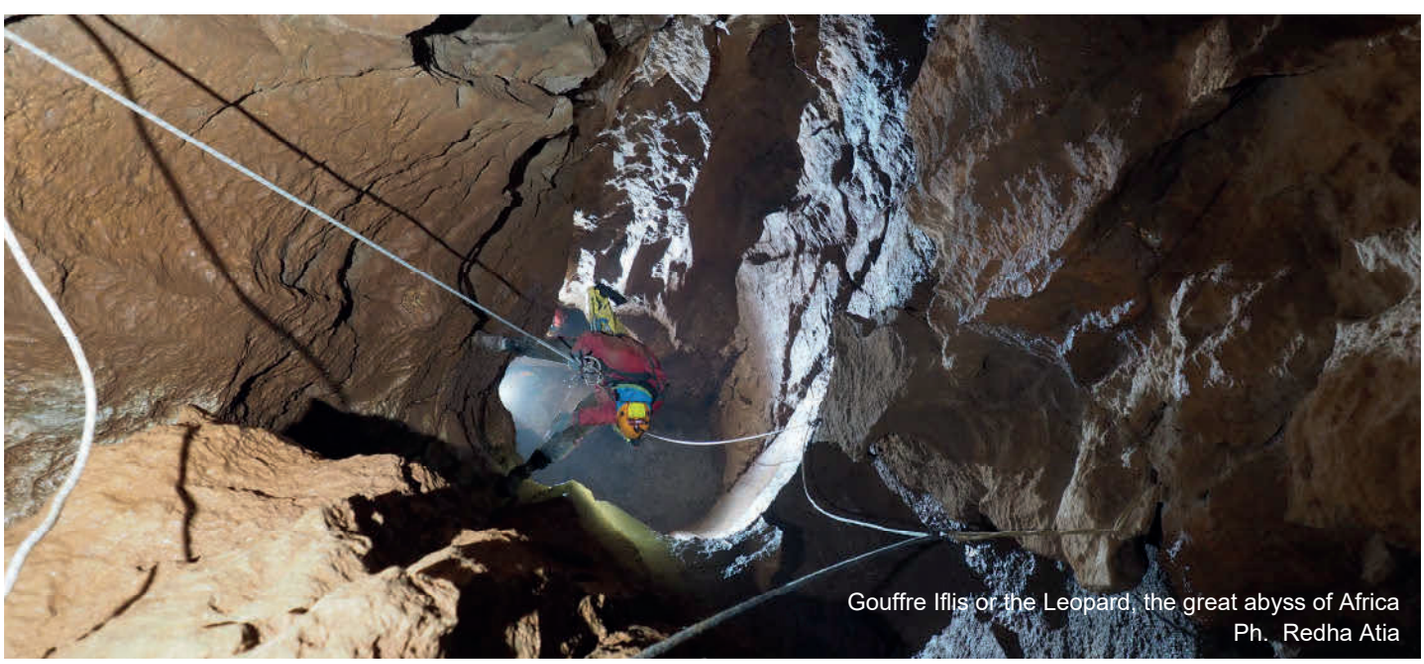
Lake Goulmine is the highest in Africa, culminating at 1,747 meters
Ph. Redha Atia

## NUMBER OF REGISTERED CAVES: 554

| Longest caves | |
|---|---|
| **Name** | **Length (m)** |
| Underground river la TAFNA, GHAR BOU'MAZA (TERNY, TLEMCEN) | >18,400 |
| Cave KEF EL KAOUS (Mountain TRARAS- Honaine, TLEMCEN) | >4,160 |
| Abyss ANOU BOUSSOUIL (Mountains Terga M'ta Roumi- Djurdjura, BOUIRA) | >3,200 |
| Cave AIN BIR TESSAA EL KBIRA (TLEMCEN) | >2,205 |
| Underground river GHAR EL KHAL (mountains Sidi Blal, TLEMCEN) | >2,210 |

Underground river la Tfna
Ph. Ainouche Abdelhamid

| Deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| Abyss Anou Ifflis “Leopard” (Mountain Ras Timedouine – Djurdura, BOUIRA) | -1,150 |
| Abyss Anou BOUSSOUIL (Mountains Terga M’ta Roumi- Djurdjura, BOUIRA) | -805 |
| Abyss Anou ACHRA LEMOUN (Mountains RAS Timedouine-Djurdjura, BOUIRA) | -323 |
| Abyss Anou INKER TEMDAT ( Djurdjura’s Mountains) | -273 |
| Abyss Anou THELDJ | -255 |



Gouffre Iflis or the Leopard, the great abyss of Africa
Ph. Redha Atia

## MARINE CAVES: 17

With its 1,622 km of Mediterranean coastline, Algeria has enormous tourism potential. As much as the beaches accessible by car are crowded with people in summer, the natural sites that are difficult to access are preserved from frequentation and human degradation, as boating is not very developed at the moment. There are bands of several tens of kilometers still untouched by any construction. The privileged few who have a boat can explore exceptional sites and enjoy them in peace.

The exploration of sea caves in Algeria began in the 1980 in parallel with the exploration of siphons in terrestrial caves that were already located before. In 1990, an expedition was organized between the SCOF of France and the Spéléo club of Boufarik, as part of a cultural and sporting exchange in western Algeria. The main objectives of the expedition were to dive the siphons listed in 1983 and 1988 in the Tlemcen Mountains, the prospecting of new karstic areas in this region and that of the Traras and the systematic exploration of the porches that border the main coastal cliff of the region. About fifteen submarine caves have been explored mainly faults dug by the surf that do not exceed twenty meters, but some are true ramified karstic cavities, the longest opens to more than 60 m. This year Yacine NEDJAA of the CSB become the first Algerian caving diver.

In 2017, still in the same region, 50 km west of Oran a team made up of Tarik Mokhtari, Fouzi KHELOUFI, Khaled BELHORMA and Amine ROUBA, well equipped for this kind of diving, tackled the exploration of  a sea cave at Cape Figalo for objective, to solve the enigma of the drowned part of this cave. After the 110 m of development, the team was able to progress 40 m more in the submerged part. The 4 explorers to whom the Cap Figalo cave has revealed all its secrets gained the desire to go in search of other exceptional sites. It won't be difficult to find such beautiful and mysterious ones. Underwater exploration in Algeria is still in its infancy and has a bright future ahead of it.

Grotte Cap Figalo
Ph. Amine Rouba

## ARTIFICIAL CAVES

Algeria has an important heritage of artificial cavities and galleries which are unfortunately not listed or inventoried, their uses vary across the cultures and human civilizations for which they were designed over the past centuries. We can classify its artificial cavities according to their main destination. We can also divide them into several categories, Among the most important ones, the hydraulic works mainly in the north, pointing at the previous genius civilizations that have exploited water resources. Military works were also marked during that time especially in the northwest in Oran, where the largest network of underground galleries in the country is located, we also have a large number of mining works that torment the Algerian Karst, while most of them are abandoned and terminated.  Managed by the national agency of mining activities ANAM, there are also caves and rock shelters which have been fitted out as spiritual and places of worship. In

time they became places of pilgrimage for certain scholars who travelled and became exiled in Algeria. Most of these places were exploited as sacred and ritual places of belief, such as like the famous cave of Ghar DJEMAA, east of Guelma. This conceals an important historical and natural heritage, among many explorers, researchers and scientists who have ventured, since the dawn of time to unveil its secrets. This mythical cave served as a refuge for Christians in the 5th century, and at its entrance are several inscriptions and engraved signs adorning its walls. These inscriptions were dedicated to Bacax, the divine and formidable god who made this cave his home. The inscriptions show that every year, in spring, the magistrates of a small town whose ruins are very close to the cave, came in great ceremonial, to make a pilgrimage and to offer a sacrifice to the god of the cave.

When talking about human occupations in the caves, we must point out the south-east of Algeria, on the borders of Niger and Libya, the Tassili n'Ajjer, where a great sandstone plateau culminates over 2,000 meters above sea level. There we can find a labyrinth of canyons and rocky peaks sculpted by erosion and wind.

This strange lunar landscape of great geological interest is home to one of the most important collections of prehistoric rock art in the world. More than 15,000 drawings and engravings, since 6,000 BC. AD until the first centuries of our era, following climatic changes, migrations of fauna and the evolution of human life on the borders of the Sahara.

The panorama of geological formations is of exceptional interest and is known as the city of Sefar. It is located in the heart of the Tassili n'Ajjer mountain range, 2,400 km south from the capital ‘Algiers’ and very close to the Libyan border. ‘Sefar’ is sometimes called "the city of stones" and this later is the largest troglodyte city in the world, with several thousand fossilized houses. It has been a World Heritage Site since 1982. However, very few travellers go there because of its geographical remoteness and difficulties of access linked to its geology.

Once you have crossed this narrow and tricky labyrinth of rocks, this extraordinary natural city is revealed. Known as the world's largest open-air museum of prehistorical art, the site is home to tens of thousands of drawings, engravings and cave paintings that were discovered in the 1950s by the famous French explorer and prehistorian Henri Lhote. Most of these paintings go back to more than 12,000 years, depicting animals and scenes of hunting or daily life, showing that this hostile place was not always an uninhabited desert. A number of these exceptional paintings depict enigmatic ceremonies as well as mysterious creatures with strange shapes and extraterrestrial appearances. The more widely known are "The Great God", "The Black Archer", "The Martians" and "The Round Heads".

| Artificial caves | |
|---|---|
| **Name** | **Lenght (m)** |
| Lake DUC (Toudja, BEJAIA) | 600 |

Echo Cave in Bejaia
Ph. Talentikit Younes

## NUMBER OF SPELEOLOGISTS: 320

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 17

## BIOSPELOLOGY

The biospeleological research in Algeria remains very poorly known and insufficient. We do not have any catalogue or precise inventory of the cave fauna. The little data we have is mainly collected during speleological expeditions.

We note the presence of species of the isopods genus such as *Proasellus dudich* (captured in 1972 in Djurdjura), *Proasellus hypogeus* (captured in the waters of the "Ifri-Bou-Amane" cave), *Proasellus gauthieri* (captured in 1928, in the gullies of the Rhar-Ifri cave, in the Djebel Bou-Zegga (35 km east-south-east of Algiers). Other species belonging to the diplopods genus, found essentially in the Djurdjura National Park and the Chréa National Park, such as *Cylindroiulus (Phalloiulus)* distinctus, *Cylindroiulus (Phalloiulus)* aff. algerinus, *Archipolydesmus fodili* n.sp.

It is also worth mentioning the existence of 26 species of mammals belonging to the order Chiroptera, such as *Rhinopoma cystops* (reported and photographed in a cave in the vicinity of Bechar), *Rhinopoma microphyllum* (reported in Boukais, near Bechar).

On the other hand, a recent study on microorganisms in the Chaabe cave in Tlemcen was carried out with the objective of searching for new antibiotics based on microorganisms such as Streptomyces spp. and Penicillium spp.

The groundwater environment offers significant ecological diversity, as shown by the European fauna, endemic species, located in the waters of a karst massif. It is certain that future surveys will enrich this fauna.

## LEGAL STATUS OF CAVES AND PROTECTION RULES

In Algeria, there are no direct laws for the protection of caves, whether natural or artificial, the legislators have never proposed laws for a better care of this natural or artificial heritage.

There are also special laws on mineral waters, mining activities, archaeology, cultural and natural parks and regional laws. To start with and more precisely, we can quote the Law n°99-07 of 05 April 1999 relating to the Moudjahed and the Chahid, title 5: historical and cultural heritage, article 53: are considered high-faults and historical steles of the national liberation revolution, places of commendation, buildings, refuges, caves, etc. ....

Or Law n° 98-04 of 15 June 1998 relating to the protection of cultural heritage, Chapter II: Classification of immovable cultural property, Art. 17. Stipulates that: Historical monuments are defined as any isolated or grouped architectural creation that bears witness to a given civilization, a significant development and a historical event.

This includes monumental works of architecture, painting, sculpture, decorative art, prehistoric structures, funerary monuments, cemeteries, caves, rock shelters, cave paintings and engravings, etc.

These two laws allow for the protection of caves that are of historical or archaeological interest or of particular geological singularity .

However, some caves have had the privilege of being listed and others are still pending. We have among the lists of cultural goods, as for example the prehistoric cave of Afalou Bou R'mel located in Bejaia, classified under N° 28 of 08/05/2016, or the archaeological site of the caves of Gueldaman in Bejaia, classified under N° 51 of 21/08/2019.

Grotte Kaf el Kaous
Ph. Atia Redh

Moreover, other caves are classified among the sites and natural monuments as for example the cave of Bou-Akkous located at Tebessa, classified under N° 07 of 23/01/1968, or the caves of Tiaret which relate to the tradition of the historian Ibn Khaldoun classified under N° 07 of 23/01/1968, also the caves of Djbel Taya at Guelma which benefited from a classification under N° 07 of 23/01/1968.

We also have another classification which is retained among the sites and historical monuments, for example the Dolmens and Funeral Caves in Guelma, they are classified by order N° 07 of 23/01/1968, or also the prehistoric cave of the oued in Saida, classified by order N° 87 of 08/12/1999.

Algeria has several caves which have a particular interest, whether it is that of an archaeological discovery, or of a favorable geographical position or of a historical interest.

It should also be noted that the creation of a natural and cultural park or a reserve is often the ideal and most solid form for the protection of caves and karst areas located in these parks. Since 2008, Algeria has created 5 cultural parks and 11 natural parks.

The Ministry of Culture is also involved in the preservation of biodiversity. Its actions are implemented through the establishment of a Master Plan for archaeological and historical areas. This is based on the law on the protection of cultural heritage and the national land use plan (SNAT). As such, among the objectives of the new policy of planning and sustainable development of the territory, there is provision for "the protection, development and rational use of heritage, natural and cultural resources and their preservation for future generations".

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# CROATIA

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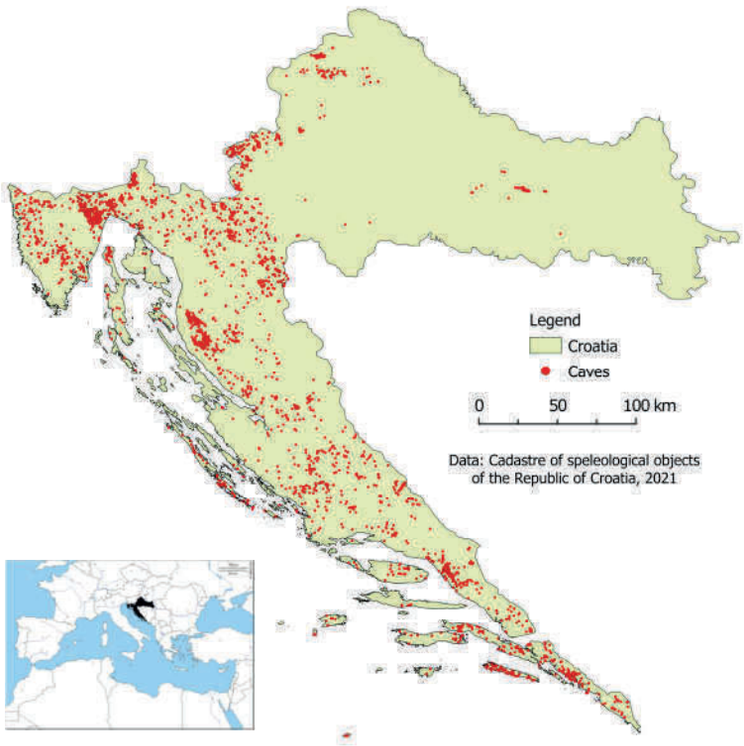
Jama kod Borovog groba
Ph. Dinko Stopić

## GENERAL INFO

In the total area of Croatia (56,594 km$^2$) karst relief occupies around 44% of the territory (including Adriatic islands; the submerged karst of the Adriatic Sea bottom excluded). Croatian karst area can be divided in two main regions: *classical Dinaric karst belt* and *isolated karst* of low mountains and hilly areas in Pannonian basin and its SW border zone towards Dinarides. Karst is developed in Mesozoic (Triassic to Cretaceous) and Cenozoic (Paleogene and Neogene) carbonate rocks (limestones, dolomites, carbonate breccias and conglomerates). Besides karst there is the fluviokarst developed mostly in terrains in dolomites, and in the zones of less permeable limestones. Caves appear both in karst and fluviokarst. The highest density and greatest diversity is in the areas of the Dinaric karst. Areas of isolated karst known for larger or numerous caves are Medvednica (Veternica cave, 5,996 m long), Samoborsko gorje and Papuk. The number of caves in flysch and marl deposits is small, and the largest are Piskovica (Istra; 1,036 m long) and Špilja kod Šušnjara cave (Banovina; 564 m long).




Besides caves with natural entrances, during construction of modern highways and tunnels more than 800 caverns were discovered. One of the most known is Kaverna u tunelu Učka with underground streams used for water supply. The cavern in St. Rok tunnel (Velebit Mt.) is 1,137 m long, with vertical difference of 147 m and volume more than 850,000 m$^3$. Cavern in the tunnel of Velebit powerplant has a volume of 1,7 mil. m$^3$ and it is the largest of such caves in Croatian karst. In the vertical caverns of the tunnel Sv. Ilija in Biokovo Mt. cavers climbed 220 m of vertical passages. There are several large submerged caves developing in phreatic and epihreatic conditions: Miljacka II cave (3,365 m long, 29 m deep), spring cave Gojak (2,312 m long, 28 m deep), spring of Ličanka (1,816 m long, 48 m deep), Pećine-Veliko vrelo (1,350 m long), Zagorska Mrežnica spring (1,147 m long), etc. The deepest dive was made in the source of the river Una to a depth of -248 m.

In Dinaric karst there are located the longest caves and the deepest pits. The best explored area with the biggest &

Tounjčica cave
Ph. Dinko Stopić

deepest caves is Velebit Mt. Due to the deep karst, pits predominate there (four of them deeper than 1 km), but there are also long caves like Cave system Crnopac (54.7 km long, 797 m deep), Cerovačke caves (2 caves 4 km each) and Munižaba cave (9.9 km). Other areas known for high spatial density of caves are Biokovo Mt., Gorski kotar and Lika area, Učka and Ćićarija Mts. During the Pleistocene, the higher regions of the Dinaric Mts. were influenced by glacial and periglacial processes that influenced geomorphology, karst formation and speleogenesis. Mountain caves and pits (mostly >1,200 m asl) often contain thick layers of permanent snow and ice deposits. The rise of Adriatic Sea level in late Pleistocene and Holocene submerged parts of former mainland with caves found at the present sea bottom and along the coast and islands. Some of them are still hydrologically active as submerged springs (locally known as *vrulja*).

Besides importance as geosites, many caves in Croatia are important paleontological and archeological sites. The most important paleontological finds are the remains of animals and people from the Pleistocene and Holocene. The most common animal remains belong to the cave bear, hyena, lion, deer, rhino, elephant, etc. Some of the important sites are Vindija cave, Šandalja II cave, Veternica cave, Vrtare Male pit, Cerovačke caves, Baraćeve caves and Čampari pit. There are even more archeological sites in caves. The findings date from the Paleolithic to recent history. The most important and well-known sites are Velika pećina (Paleolithic; Ravna gora), Vela jama (Paleolithic-Neolithic; Lošinj), Vela Spila (Paleolithic-Bronze Age, Korčula), Grapčeva Cave (Neolithic, Hvar), Nakovana Cave (Neolithic-Eneolithic, Pelješac), Jama pod Vatinovcem (Bronze Age, Vrhovine), etc.

According to the official data from Cadastre of Speleological Objects of the Republic of Croatia (2021) there are 3,401 registered caves, but estimations are more than 10,000.

Spilja u kamenolomu Tounj
Ph. Hrvoje Cvitanović

## NUMBER OF REGISTERED CAVES: 3,401 (ESTIMATION >10,000)

| Most important longest caves | |
|---|---|
| **Name** | **Length (m)** |
| Cave system Crnopac | 54,709 |
| Cave system Đulin ponor-Medvedica | 16,396 |
| Cave system Panjkov ponor-Muškinja | 13,052 |
| Munižaba | 9,911 |
| Cave system Tounjčica | 9,104 |

| Most important deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| Pit system Lukina jama-Trojama | - 1,431 |
| Slovačka jama | - 1,324 |
| Nedam | - 1,226 |
| Pit system Velebita | - 1,026 |
| Njemica | - 934 |

Miljacka II cave
Ph. Nenad Buzjak

## MARINE CAVES >300 (ROUGH ESTIMATE)

| Most important marine caves/coastal caves | | |
|---|---|---|
| **Name** | **Length (m)** | **Depth (m)** |
| Vrulja Modrič | 2,898 | - 37 |
| Velka vrulja | 1,554 | - 76 |
| Vrulja Zečica | 1,210 | - 49 |
| Medvjeđa cave | 245 | - 21 |
| Pit in Lučice bay | | - 44 |

## NATIONAL CAVING ORGANIZATIONS:

- Croatian Speleological Federation (CSF) www.speleo.hr
- The Speleological Commission of the Croatian Mountaineering Association www.hps.hr/speleologija

## NUMBER OF SPELEOLOGIST: 739

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 38

## NATIONAL MAGAZINES AND MAIN SPELEOLOGICAL PUBLICATIONS:

- Speleolog https://speleolog.hr/publikacije/speleolog
- Subterranea Croatica https://hrcak.srce.hr/subterranea

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVE AND KARST:

- Department of Geography, Faculty of Zagreb, University of Zagreb www.pmf.unizg.hr/geog
- Croatian Geological Survey www.hgi-cgs.hr
- Hrvatsko biospeleološko društvo www.hbsd.hr

Mucića ledenica
Ph. Željko Marunčić Bospor

## BIOSPELEOLOGY

Since first systematic research of underground fauna (2nd half of the 19th century) 494 taxa were described from 322 cave type localities in Croatia. Based on the number of species, cave habitats are dominated by beetles with 156 described taxa. Next are crustaceans (81), snails (60), false scorpions (55), spiders (37) and diplopods (27). These six major groups account for almost 90% of the known species of cave taxa and dominate the underground habitats. Unfortunately, there is no single database with all of the recorded underground taxa, and the number of true cave species (troglobionts and stigobionts) can only be estimated to be higher than 500. The majority of cave species have very restricted range, and almost 70% are Croatian endemics. In this immense biodiversity, some areas should be emphasised, e.g. Ogulin – Plaški area, Velebit Mt., Biokovo Mt., Dalmatian islands and Dubrovnik littoral. These areas boast some unique representatives of cave fauna. The only currently known subterranean freshwater sponge *Eunapius subterraneus* inhabites a few caves in Croatia near town of Ogulin and northern Velebit Mt. From only three known cave freshwater bivalves, two species live in Croatia, *Congeria jalzici* and *Congeria kusceri*. Endemic leech *Croatobranchus mestrovi* inhabits only five deep caves of northern Velebit Mt. and the unique dipteran *Troglocladius hajdi* was recorded only in the deepest Croatian cave Lukina jama - Trojama cave system.

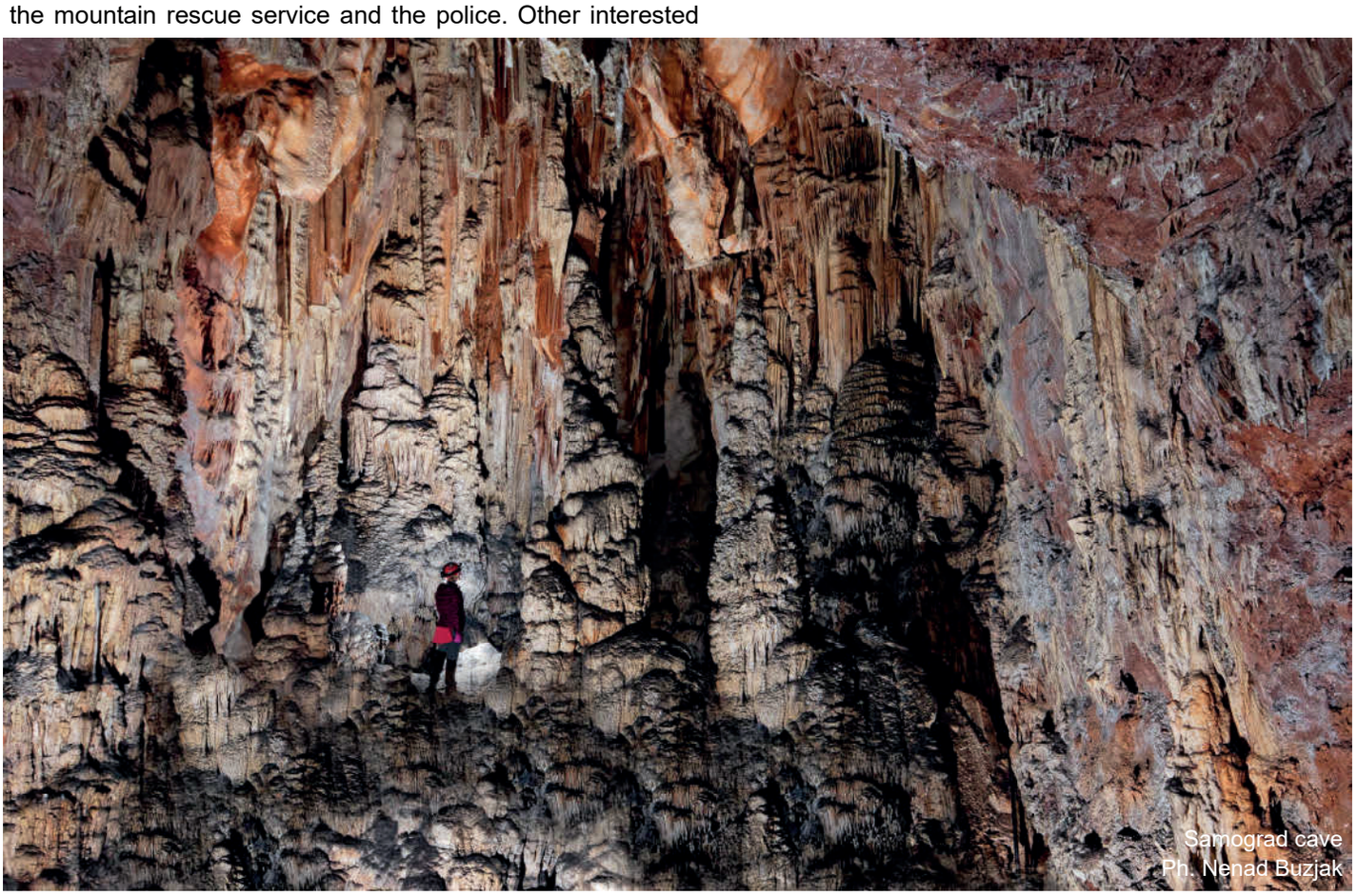
According to IUCN threat status 70 taxa are vulnerable (VU), 65 critically endangered (CR), 49 endangered (EN) and for 2 taxa there are not sufficient data to determine the threat status (DD).

New species from Rhagidiidae family.
Lukina jama-Trojama cave system
Ph. Martina Pavlek

## LEGAL STATUS OF CAVES AND PROTECTION RULES

The main ways of formal protection of caves are realized through the Nature Protection Act (NPA), the NATURA 2000 ecological network and spatial plans on the state, regional and local level. According to the NPA, caves are of special interest to the Republic of Croatia and enjoy its special protection. Although it does not specifically define the reasons for that interest, it is about significance due to unique habitats, underground aquifers, geodiversity and geoheritage, and cultural significance. The law requires that any discovery of a new cave must be reported to the Ministry in charge of nature protection, but this should only be the case when the discovery occurs during construction and similar works and when there is a danger of degradation or destruction. The law prohibits the devastation, and especially the damage and removal of speleothems, fossil and archaeological finds, as well as waste pollution and changes in habitat conditions. For speleological research and for any other activities in caves and surface above them, it is necessary to obtain the permission of the Ministry or regional administration with the consent of the protected area or institution in whose territory they are located. According to the NPA, the Ministry has established and maintains the Cadastre of Speleological Objects of the Republic of Croatia. The cadastre is primarily filled with data from caving clubs and some professional organizations. In addition to cavers, the cadastre give access to the nature protection sector, the mountain rescue service and the police. Other interested

Archeological site in Bobinac Kozerina
Ph. Hrvoje Cvitanović



Samograd cave
Ph. Nenad Buzjak

parties can obtain the data through the owners of submitted data. The public review is available through Bioportal (www.bioportal.hr). The protection is relatively well organized, but occasionally problems arise due to insufficient efficiency, overlapping competencies of different sectors and environmental incidents related to examples of pollution and illegal waste disposal. Caves are the best protected within protected areas or individually as natural monuments (geomorphological, geological, paleontological or hydrological). Depending on the protected area type, they are managed by a public institution established by the state or a regional administration with the consent of the state Ministry responsible for nature protection. All other caves are consent of regional institutions for nature protection. There are 403 caves in the NATURA 2000 ecological network: code 8310 - Caves not open to the public, 8330 - Submerged or partly submerged sea caves. In addition, caves can be found in other habitat types such as 32A0 - Tufa cascades of karstic rivers of the Dinaric Mts. They are taken care of by the administrations of protected areas and nature protection institutions of the counties. The Clean Underground initiative (www.cistopodzemlje.info/en/) plays an important role in the protection of speleological objects. Since 2015. Initiative gathered data on polluted caves from 35 speleological clubs and finance cleaning. So far, they have uncovered over 700 contaminated sites. 20 caves are on the list of protected cultural assets due to archeological findings. At the moment, there are 25 active tourist caves with various forms of tourist use, from classic visits to speleo adventures.

Waterfall in Kaverna u tunelu Učka
Ph. Mladen Jekić

Kita Gačešina
Ph. Marin Glušević

Vilina špilja izvor Omble
Ph. Hrvoje Cvitanović

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# CYPRUS

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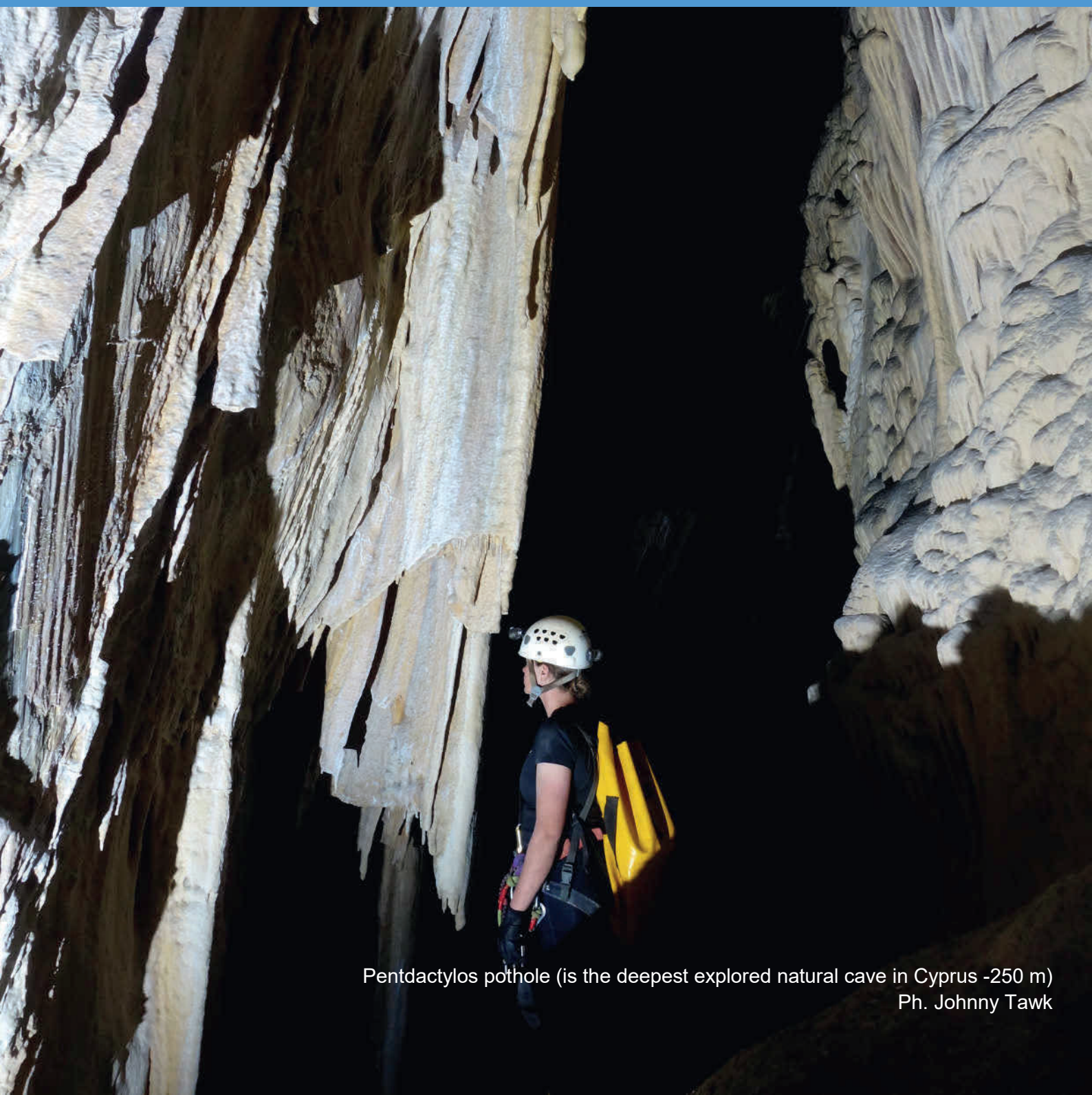
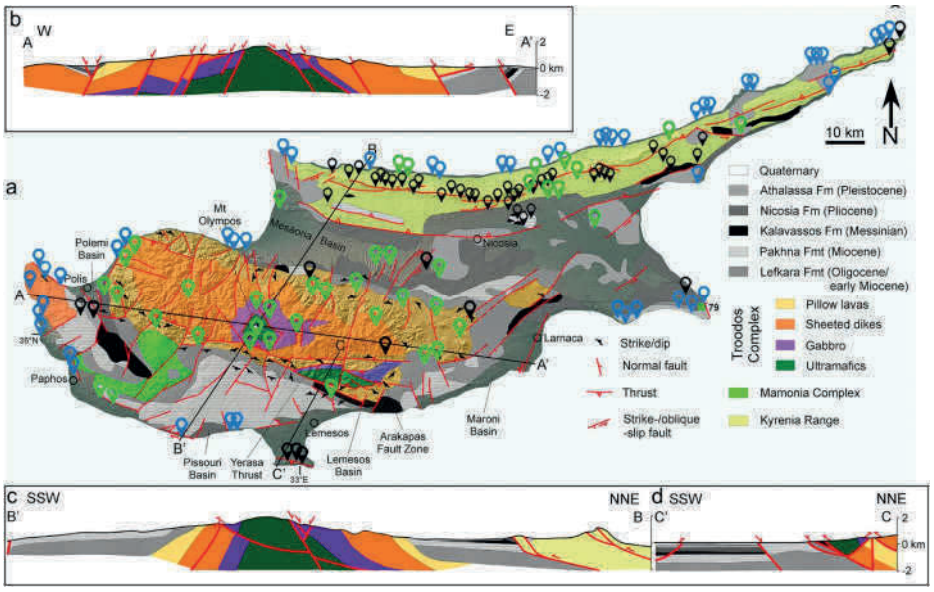


Pentdactylos pothole (is the deepest explored natural cave in Cyprus -250 m)
Ph. Johnny Tawk

## GENERAL INFO

The largest portion of Cyprus' limestone karst exists in the Kyrenia Range along the northern shore of the island. Longest and deepest caves are found near the Pentadaktylos formation in the middle of the range. The Kyrenia region was subject to a rapid uplift and aerial exposure since the Upper Pliocene. Most caves in the Kyrenia Range are therefore of tectonic origin, not dissolutional karst, comprising original rounded voids that were never under phreatic conditions. Cyprus' semi-arid climate and limited underground recharge (4 L/s/km$^2$) further limit the possibility of phreatic conditions in the formation of its caves.




Geological map of Cyprus with the location of caves (a). Natural caves in limestone and other rock types (black markers), marine caves (blue markers), and artificial caves (green markers) are shown, along with fault lines and rock types. A cross-section of the Troodos mountains along a W-E orientation (inset b) and of the Troodos and Kyrenia ranges along a SSW-NNE orientation (inset c) are shown with associated rock types and faults. Cross-section lines for insets are given in black (A-A', B-B') in the geological map of Cyprus (a).

There are some small karstic outcrops throughout other parts of Cyprus, most of which establish littoral (marine) caves. In the lower-elevation plains there are a grouping of gypsum caves, the most famous being Fig Tree Cave (375 m long). Most gypsum caves are small, short and horizontal, around 50 m or less in length. Around the Troodos mountain range to the west, there are mines along with small man-made passages and natural shelter caves but almost no real limestone karst.

As a result, most caves are relatively small. The majority of limestone caves are at or above 500 m in elevation, and are mostly vertically-oriented following tectonic influences and fault lines. Cyprus is unique in that it has several caves formed initially by faults and then widened exclusively by condensation-corrosion action.

## KARST AREAS

Cyprus has a unique geomorphological origin, with a diversity of geological characteristics. Two prominent mountain ranges, the limestone Kyrenia Range and volcanic Troodos Mountains, reaching their highest elevations at Mount Kyparissovouno/Selvilitepe (1,024 m) and Mount Olympus (1,952 m) respectively, are divided by the sedimentary Mesaoria Plain. Cyprus' current landform began 90 million years ago when magma rose from between the African and Eurasian plates during the Upper Cretaceous, leaving behind the volcanic rock that currently forms the Troodos Terrance. During the Miocene, 20 million years ago, the African plate began to move under the Eurasian plate. These plate shifts started to lift the cooled magma, now the Troodos Terrane, from the sea. By the Upper Miocene, 10 million years ago, the land mass that would become the Troodos Mountains was further exposed above the sea by uplift from the subduction of the African Plate, while the limestone Eurasian Plate was uplifted to form the beginnings of the Kyrenia Range. The Mesaoria Terrane was still under the sea, allowing sediments to deposit, but by the Pliocene and Pleistocene, 3-5 million years ago, the Mesaoria Plain had risen above the water as well, connecting the two mountain ranges. The summit of Mount Olympus eroded such that the Earth's mantle is now exposed directly to the surface creating the Troodos Ophiolite complex (exposed oceanic crust and mantle). Meanwhile, the Kyrenia range's fault lines were set at approximately 30 degrees (N30°E), a result of the Eurasian plate tilting during uplift. The resulting strike-slip faults in the Kyrenia Terrane formed the basis for modern-day tectonic caves in the region and created the iconic Pentadaktylos (Five Fingers) formation.

The gypsum outcrops of the Mesaoria Plain are believed to have been formed from primarily condensation-corrosion processes along existing fault lines, with possible additional reshaping from more recent seismic activity and/or erosion from microbial processes. On the other hand, marine caves along the coastline are situated in recent calcarenites and are

generally younger than the limestone caves of the Kyrenia region or the gypsum caves of the Mesaoria Plain. Most features in the Troodos region are man-made tunnels carved originally for mining or prospecting purposes, although some tallus or natural shelter caves exist in this volcanic rock as well.

## NUMBER OF REGISTERED CAVES: ~350

500< natural and artificial caves are recorded in Cyprus and can be grouped in five different types: I) fracture-caves mainly located in the Kyrenia Range; II) gypsum caves located in the Messinian gypsum of Mesaoria basin; III) marine caves located in recent calcarenites around the whole island; IV) artificial caves, abandoned mines, shafts and small passages along the Troodos Range; and V) sandstone mines around Nicosia (e.g. Mammari, Acropolis and Ayia Paraskevi etc).

Smokey cave
Ph. Didier Cailhol

**Most important caves**

| Name | Length (m) | Depth (m) |
|---|---|---|
| Fig Tree Cave | 375 | - 13 |
| Pentadactylos Pot Hole | 300 | - 250 |
| Hot cave | 168 | - 42 |
| Varathro Akama | 110 | - 80 |
| Smokey Cave | 93 | - 35 |

Incirli Cave (is the longest explored natural cave in Cyprus 375 m)
Ph. Salih Gücel

## MARINE CAVES: ~70

The caves can be found around the shoreline of Cyprus from Akamas to Karpasia Peninsula, as far as the geology allows the formation of such caves. The majority can be found in karstic formations, but some can also be found at the western part of the Troodos Ophiolite complex where the volcanic formations extend into the sea.

**Most important marine caves**

| Name | Length (m) | Depth (m) |
|---|---|---|
| Agia Napa Sea Caves | 900 | 0 |
| Pegia Sea Cave | 82 | 0 |
| Halavro Sea Cave | 40 | 0 |
| Cyclops Cave | 25 | + 3 |
| Agioi Saranta Cave | 18 | + 5 |
| Kokoskali Cave | 17 | - 9 |

## ARTIFICIAL CAVES TOTAL: ~50

There are many artificial caves, tunnels shafts and abandoned mines along the Troodos Range. The most important one is the Amiandos Tunnel with a total length of 2,000 m, hosting important bat populations. The longitudinal mining history on the island has left many artificial sites many of which are still unknown, especially at the areas where the volcanic and limestone formations meet. Additionally, there are some extensive abandoned sandstone mines around Nicosia (e.g. Mammari, Acropolis, Ayia Paraskevi etc).

Artificial caves are visited mainly for recording and counting the populations of different bat species. Such visits are made in artificial tunnels, abandoned mines and shafts. Although there are many areas with underwater galleries no cave diving activities have been recorded.

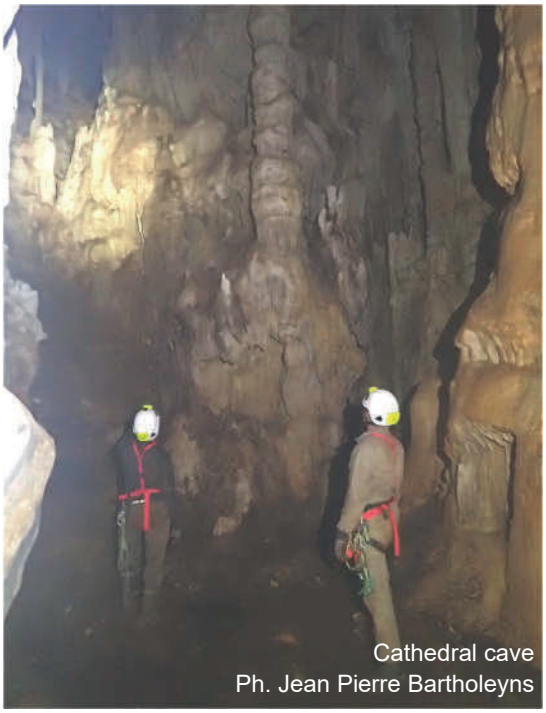
**Most important artificial caves**

| Name | Length (m) | Depth (m) |
|---|---|---|
| Amiandos Tunnel | 2000 | +200 |
| Kalavasos Mine | <800 | -600 |
| Lapithos Spring Tunnel | 80 | +3 |
| Mammari Caves | 200 | -2 |
| Koma tou Gialou / Kumyalı Caves | 120 | -5 |

## NUMBER OF SPELEOLOGISTS: ~30

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 2

| Group | Year | |
|---|---|---|
| Mağara Meraklıları Derneği (Cave Enthusiasts Association) | 2014 | MAGMER |
| Cyprus Speleo Club | 2020 | CSC |



Cathedral cave
Ph. Jean Pierre Bartholeyns

## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLISHING

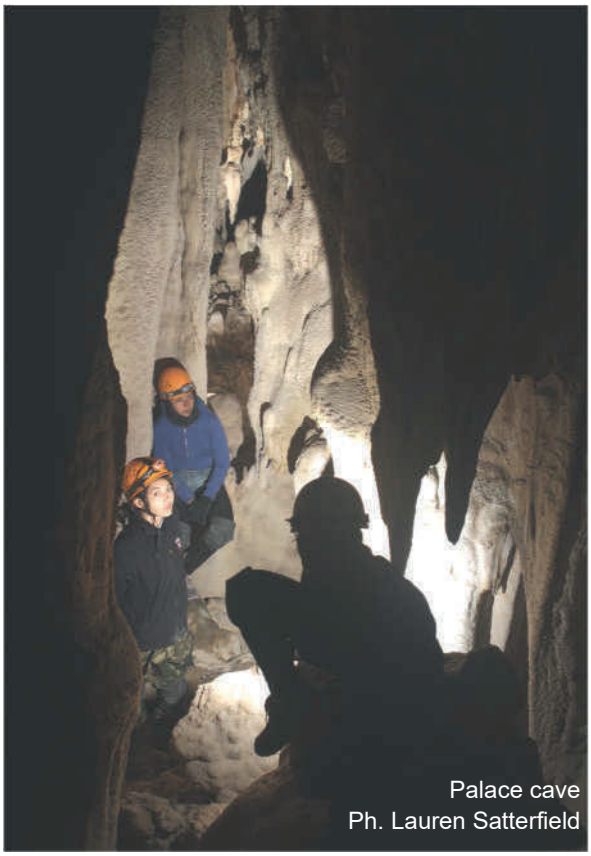
There is no national magazine focusing on speleological research.

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST

Some speleological studies, focusing predominantly on artificial caves, are conducted by the Geological Survey Department. Relevant information can be found in the 'Annual Reports' and 'Data and Publications' that can be accessed at the Departments' website:

http://www.moa.gov.cy/moa/gsd/gsd.nsf/dmlIndex_en/dmlIndex_en?opendocument

In addition, the Department houses a library that has to be visited in person as it is not available online.


Palace cave
Ph. Lauren Satterfield

## BIOSPELOLOGY

Caves are classified under the Habitats Directive (92/43/EEC) of the European Union as habitats *8310 Caves not open to the public* and *8330 Submerged or partially submerged sea caves*. In the southern part of Cyprus, such caves have been identified and classified in the Natura 2000 Network depending on flora and fauna that they host. The major fauna species include the Mediterranean monk seal (*Monachus monachus*), various bat species and some invertebrates. Despite the classification and conservation applied to these caves, current knowledge is at a preliminary stage and more research is necessary.

In the northern part of Cyprus, a EU-funded project conducted from 2016 to 2019 on 'The Caves of Kyrenia Mountains Project: Research, Conservation and Education', identified important caves on the Kyrenia Range as potential Natura 2000 sites once a Cyprus settlement enters into force and EU rules will apply over the whole island. During this project, new species of invertebrates were described for Cyprus that were not known before 2004, which can be suggested as new additions to the species list of the Habitats Directive. In general, caves in Cyprus host a wide range of speleobiology despite their relatively small size. Most prominantly studied among the biota of Cyprus' caves are its bat species, while arachnids and other invertebrates have been documented as well. A troglobite spider of the family Leptonetidae was found in 2015 but could not be described due to the sample being a juvenile. Two species of Dysderidae (*Dysderocrates kibrisensis* and *Harpactea kalavachiana*), the first records of the family to be found in Cyprus, were discovered and described during the previously mentioned project. Other invertebrates known to exist in Cyprus' caves include woodlice (order Isopoda) and pseudoscorpions (order Pseudoscorpiones).

There are 20 bat species that have been confirmed on Cyprus during surveys from 2014-2019, of which at least 18 use caves for roosting or hibernation habitat. One additional species was documented in older surveys but has not been confirmed recently. These species span both sub-orders of Chiroptera, Yinpterochiroptera and Yangochiroptera, across five families (Pteropodidae, Rhinolophidae, Vespertilionidae, Miniopteridae, Molossidae) and 10 genera (Rousettus, Rhinolophus, Myotis, Eptesicus, Hypsugo, Pipistrellus, Nyctalus, Plecotus, Miniopterus, Tadarida). Cyprus' cave-dwelling bat species include the Egyptian fruit bat (*Rousettus aegyptiacus*) and two cave-dwelling species with "Vulnerable" global conservation status, Mehely's horseshoe bat (*Rhinolophus mehelyi*) and the Long-fingered bat (*Myotis capaccinii*).

Cyprus is famous for fossils of extinct fauna found in many caves in the region. Most notably, fossils of the Cyprus dwarf hippopotamus (*Hippopotamus minor*) and Cyprus dwarf elephant (*Palaeoloxodon cypriotes*) were found in caves, the latter of which was famously discovered in 1902 by Dorothea Bate. Both species are believed to have gone extinct during the Holocene approximately 11,000 years ago. Other work on paleontology has identified fallow deer, softshell turtles, genets, and various rodents. Much more research is needed on the biota in Cyprus' caves.

## LEGAL STATUS OF CAVES AND PROTECTION RULES

The Republic of Cyprus was established in 1960, after the former colony gained independence from Britain. Since 1974, a de facto division of the island has existed, with the **"**Green Line**"** separating the two parts of the island. The Greek Cypriot community lives in the southern part of the island, and the Turkish Cypriot community in the northern part of the island. Therefore, Cyprus joined the EU on 1 May 2004 as a de facto divided island. While the whole of Cyprus is EU territory, EU legislation is suspended in the northern part of the island, including effective suspension of the EU's environmental acquis. The situation will change once a Cyprus settlement enters into force and EU rules apply over the whole island.

The Geological Survey Department, based in the southern part of the island, safeguards the public interest though permitting any geological related activity. Furthermore, it consults with other departments based in the southern part of the

island (e.g. Environment Department, Forestry Department etc) for the protection and conservation of any flora, fauna and other resources that might be present in an area.

In the northern part of the island, no legal protection exists for caves in the Kyrenia Mountains. The area is threatened by mining activity and by damage from uninformed visitors. Permanent damage has already been done to many caves via broken formations and digging into caves to find artifacts.

Moreover, a long tradition of killing bats through burning caves may have drastically reduced bat populations on the island. Originally the killing of bats was sanctioned by the British authorities when Cyprus was under British rule, because bats were designated as agricultural pests, particularly of fruit crops. Thus, fruit bats were the primary targets of extermination efforts but methods (e.g. setting a fire in a cave to suffocate bats with smoke) targeted not only fruit bats but all bat species. This practice is now illegal but still persists in some areas.

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## DATA DISCLAIMER

This info card has been produced with data collected by Cypriot cavers. Its contents are the sole responsibility of the Mağara Meraklıları Derneği (Cave Enthusiasts Association) and the Cyprus Speleo Club and do not necessarily reflect the views of the authors of this book.

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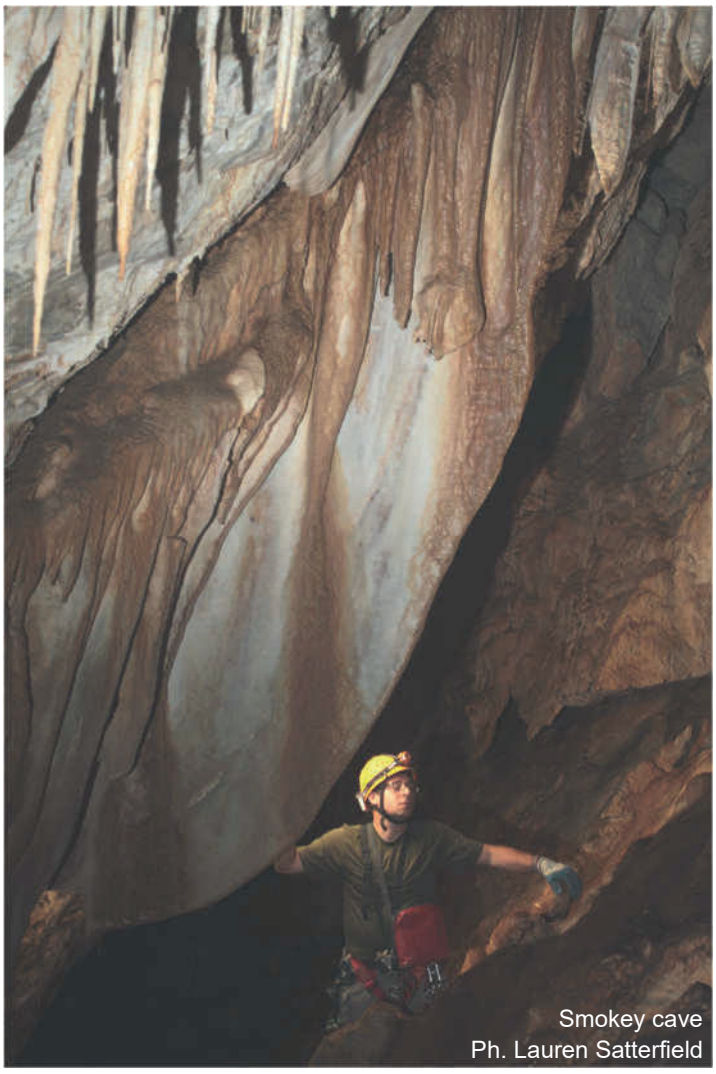

Smokey cave
Ph. Lauren Satterfield

# EGYPT

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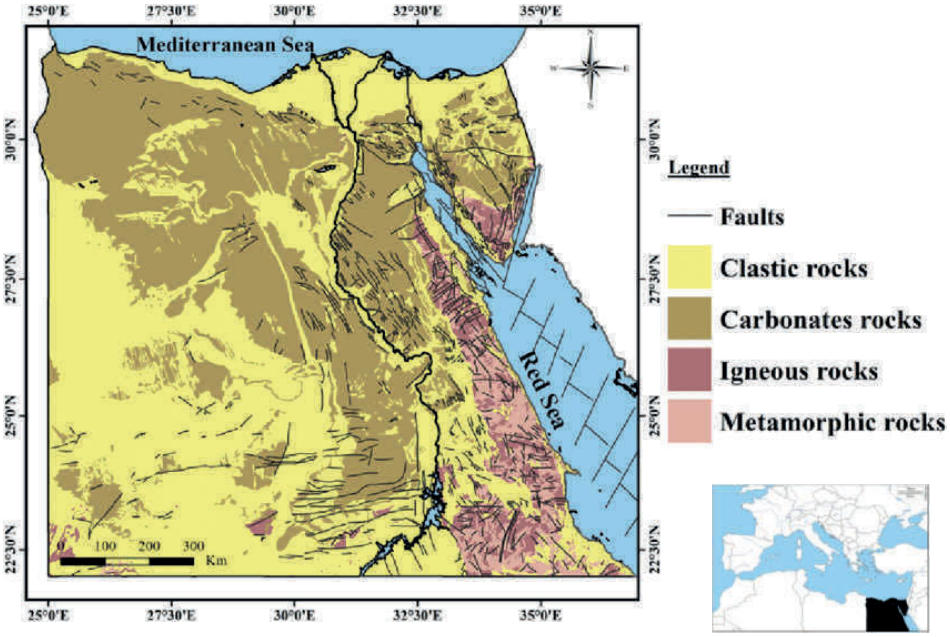
Djara cave
Ph Rosario Ruggieri

## PHISICAL AND LITHOLOGIC NOTES




Simplified geological map of Egypt, modified after a geological map of Egypt on the scale 1:2 million ©Geological Survey of Egypt (GSE, 1981).

From a morphostructural point of view, the Egyptian Sahara is partible in three wide plateau, separated by depressions. The first plateau, constituted by upper Cretaceous sandstones, rises up to 1,000 m in the distant southern area, grows gradually thin as far as gentile shallows to the Dakla and Kharga's depressions. Than rises up from the latter, forming the central desert's second plateau, constituted by Eocenic limestones, starting to slope down from its upper level of 540 m, to an average of 50 m under the sea level of the Quattara's depression for about 400 km towards the north. This eroded rough massif is bounded by the Nile's valley and by the westwards Great Sand Sea dunes. The plateau's surface is pierced by the big Farafra, Bahariyya and Fayoum's depressions, as well as by dozens of minor depressions (Rayyan, Arag, Sitra and others). Finally, the northern Miocenic plateau, forms the calcareous relief between Quattara and the Mediterranean Sea, spreading for 600 km between the eastwards Nile delta and the westwards Cyrenaic plateau. This plateau degrades gradually from 200 m along the Quattara depression's ridge till it laps northwards on the Mediterranean Sea (G.H. Awad, et al., 1966. AA.VV.,1982).

## MOST IMPORTANT CAVES

**Djara cave.**

Cave located in the western desert, Djara Region, it is developed in two levels, the lower, characterized prevalently by detrital and calcitic morphologies and deposits, the higher, characterized by mineral fillings morphologies and corrosion morphologies. Over some blocks, in the vicinity of the entrance, bovine and antelope drawings represent the desert's conditions about 7,000-8,000 years ago, before the starting of the actual dry phase.

**Djara cave 2.**

Cave located 3 km westsouthwest of Djara cave there is a second cave, called Djara 2, smaller than the previous and constituted by a wide chamber with a 10 m deep shaft entrance. In the walls there are some particular eccentric gypsum's mineralizations, while on the ceiling it is possible to see some small domes due to condensation/corrosion process.

**Sannur cave.**

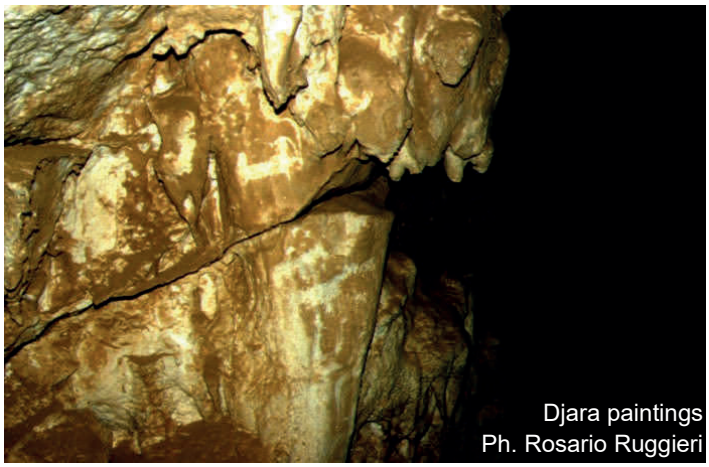
Cave located In the eastern desert about 60 km far from Beni Suef, in the Wadi Sannur. The cave, located in an area interested by an alabaster quarries, is at the moment with 275 m of development the longest cave of Egypt. This cave, with the entrance located on a vertical wall a few meters from the bottom of an abandoned alabaster quarry, develops along a semicircular tectonic structure cutting obliquely, at about 45°, the Eocene limestone formation. The cave is actually interesting for an important project of safeguarding, improvement and tourist enjoyment made by the Egyptian Environment Protection Agency.

**Hamman pharaoh 1 e 2 caves.**

Caves located in the Sinai, area of Ras Serid-Abu Zenena, a few meters from the shore of Red Sea. The two caves, belonging to the same karst system, owe their origin to hypogenic phenomena connected with the rising of hot thermal fluids from the deep subsurface. The Hamamm 1 cave, explored only partially because of the prohibitive condi-

tions of temperature, above 50°C, showed the presence of a hot water stream springing outside in the shore through some pools. The second cave located near the first one, and characterized by lower temperatures, showed a labyrinthic structure with conduits developed along the bedding of layers and fractures. The deep hypogenic genesis of this system was also testified by the presence of deposits of gypsum filling some doms on the ceiling and walls of the cave.

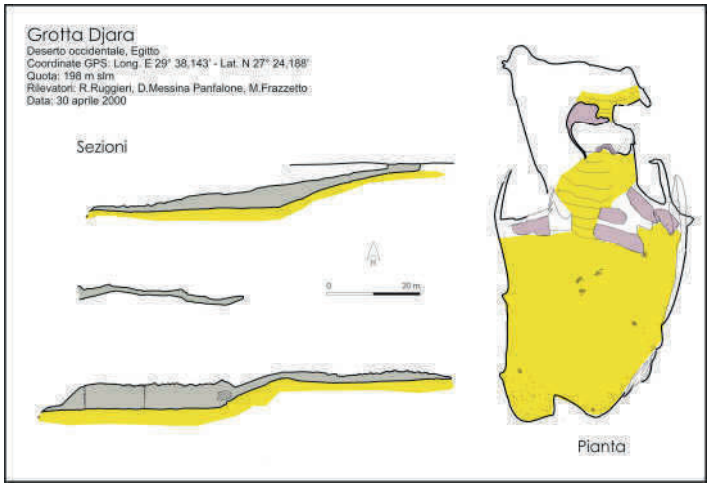
Djara cave
Ph. Rosario Ruggieri



Djara paintings
Ph. Rosario Ruggieri

**Most important longest caves**

| Name | Length (m) |
|---|---|
| Sannur cave | 275 |
| Hamman pharaoh 2 cave | 126 |
| Degla 2 cave | 88 |
| Djara cave | 73 |
| Karnak 2 cave | 40 |

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# FRANCE

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**Collaborators: Michel Wienin, Marie-Clélia Lankester**
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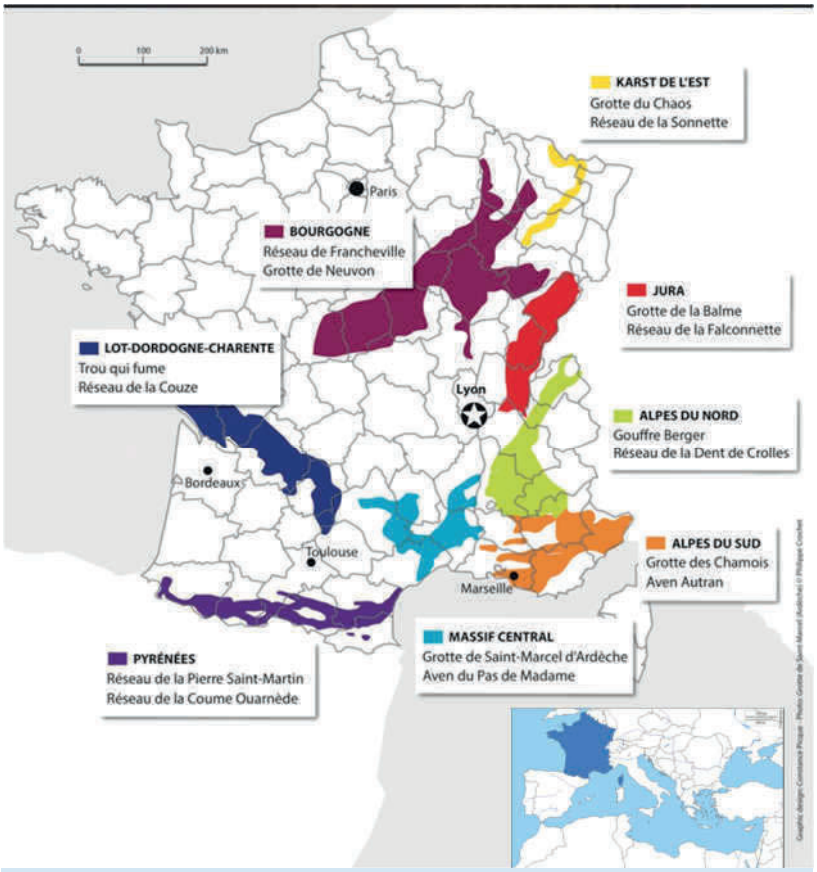
Grotte de Saint-Marcel (Ardèche)
Ph. Philippe Crochet

## GENERAL INFO

In France (surface 55,1695 km²), areas of speleological interest characterized by rocks that favour the formation of natural cavities represent about 40 % of the entire land. Not every region has notable areas in their territory. There are significant differences in numbers, extension and types of caves.

This feature has spurred speleological explorations in the French territory for over a century.

Over more than a century of explorations, more than 50,000 caves have been discovered, explored and documented, mainly in carbonate rocks (limestones and dolomites). There are also a few caves in gypsum and sandstone but this is not a common feature. Caves in volcanic rocks are more present overseas.



Karst area in France (Map: Constance Picque)

## KARST AREAS

All French regions include karstic areas with very significant differences in terms of size. For instance, in the Armorican massif (area of 65,000 km²), only 20 small caves are known and in the Ain department (area of 5762 km²), there are more than 2700 karstic phenomena and there are new discoveries almost every year.

The extensive karstic areas in France, and the proximity with notables cities, have encouraged systematic explorations in various type of carbonated rocks for more than a century.

The most known important karstic systems are developed in carbonated rocks (limestone and dolomite): the *Réseau Felix Trombe* (also known as *Coume Ouarnéde complex*) is the largest French cave system explored with more than 117 km of development in the Central Pyrenees; the Gouffre de la Pierre-Saint-Martin (also known as Gouffre Lépineux – Lépineux Pit) in Western Pyrenees with more than 83 km of development; the Réseau de l'Alpe (Alpe's complex) in the Chartreuse mountain with more than 72 km of development; the *Arresteliako Ziloa* in West Pyrenees with ~61 km of development; the Gouffre de Padirac in the Causse de Gramat with ~59 km.

Less extended, but yet really interesting, are also the gypsum caves in the Alps (Savoy and Maritime-Alps) and also in the Parisian Basin (near Paris).

France offers an extremely complex speleological scenario, continuously updated thanks to the unceasing activity of exploration and research throughout its territory.

## NUMBER OF REGISTERED CAVES: ~500,000 *(EXCEPT MINES)*

| Longest caves | |
|---|---|
| **Name** | **Length (m)** |
| Réseau Felix Trombe (*Henne-Morte and Coume Ouarnede massif - Haute-Garonne*) | > 117,000 |
| Gouffre de la Pierre-Saint-Martin (*Pierre Saint-Martin massif – Pyrénées-Atlantiques*) | > 83,000 |
| Réseau de l'Alpe (*Chartreuse massif - Isère*) | > 72,000 |
| Arresteliako Ziloa (*Pierre Saint-Martin massif – Pyrénées-Atlantiques*) | ~ 61,000 |
| Grotte de Saint Marcel *(Bidon- Ardèche)* | ~ 60,000 |
| Gouffre de Padirac (*Causse de Gramat – Lot*) | ~ 59,000 |

Grotte de Champclos (Gard)
Ph. Philippe Crochet

| Deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| Réseau Lucien Bouclier or Gouffre Mirolda (*Samöens - Haute-Savoie*) | - 1,733 m |
| Réseau du gouffre Jean-Bernard (Samöens - *Haute-Savoie*) | - 1,602 m |
| Gouffre de la Pierre-Saint-Martin (*Pierre Saint-Martin massif – Pyrénées-Atlantiques*) | - 1,410 m |
| Réseau du Gouffre Berger (Vercors massif - Isère) | - 1,271 m |
| Gouffre du Bracas de Thurugne (*Pierre Saint-Martin massif – Pyrénées-Atlantiques*) | - 1,170 m |

Grand Aven d'Orgnac (Ardèche)
Ph. Philippe Crochet

Grotte de Croze (Hérault)
Ph. Philippe Crochet

## Marine caves: ~1000

*But regroup submerged cave complex and marine caves sensu stricto.*

**Most important marine caves**

| Name | Length (m) | Depth (m) |
|---|---|---|
| Emergence du Bestouan | ~3750 | -33 |
| Emergence de Font Estramar | ~2900 | -286 |
| Emergence de Port-Miou | ~2350 | -233 |
| Grotte du Diable (Huelgoat-Finistère) | 180 | - |
| Grotte du Rocher du Serpent (Plougastel-Finistère) | 150 | - |

Grotte de Saint-Marcel (Ardèche)
Ph. Philippe Crochet

## ARTIFICIAL CAVES: SEVERAL THOUSANDS

In France, the official statistics include undergrounds, tunnels, different types of quarries.

**Most important artificial caves**

| Name | Length (m) | Depth (m) |
|---|---|---|
| Grand réseau sud (Paris) | > 100 km | ~ -20 m |

Grotte de Clamouse (Hérault)
Ph. Philippe Crochet

## NATIONAL CAVING ORGANIZATION

Fédération Française de Spéléologie (since 1963)

## NUMBER OF CAVERS:

15,000 approx., but 6564 with a federal licence (in 2020)

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 388

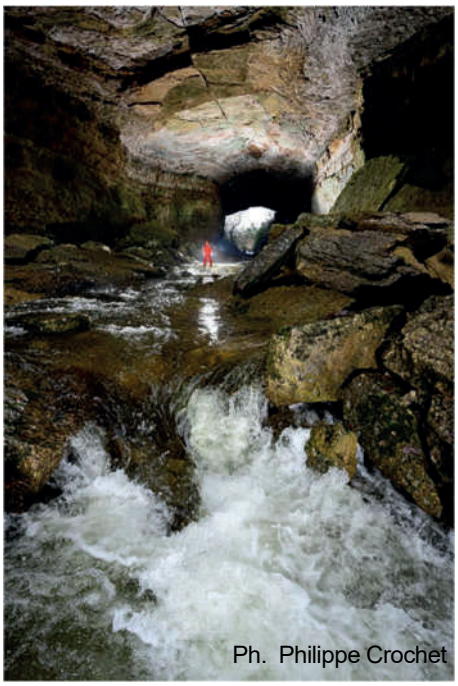
## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLICATION:

- Spelunca
- Karstologia

and some federal publications:

- Info-EFS
- Les cahiers de l'EFS
- Spéléoscope
- Info plongée
- Le descendeur

See https://publications.ffspeleo.fr/



Ph. Philippe Crochet

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST:

- Laboratoire EDYTEM (Université Savoie Mont Blanc)
- Muséum National d'Histoire Naturelle de Paris (MNHN)
- Association Française de Karstologie (AFK)
- Association de Recherche Spéléologique Internationale à la Pierre Saint-Martin (A.R.S.I.P.)
- Laboratoire LEHNA (University Lyon I)
- Groupe d'Etude de Biospéologie (GEB, Fédération Française de Spéléologie, Commission scientifique)
- Association IFREEMIS.

## BIOSPELEOLOGY

The cave fauna is well known, but the studies are still in permanent evolution… The stygobitic fauna takes into account 381 species and subspecies. At least 421 species are also regarded as troglobites.

The well known zoological orders in the French cave fauna are: Chiroptera, Araneae, Palpigrada, Trichoptera, Amphipoda, Coleoptera, Orthoptera and Lepidoptera. Some groups are in complete revision: Diplopoda, Chilopoda, Opiliones, Isopoda, Oligochaeta. Other groups would deserve some new specialists: Pseudoscorpiones, Diptera, Cyclopida.

Despite more than 100 years of biospeleology studies, the knowledge of the French cave fauna is still in permanent progression thanks to the French Federation Speleology (FFS) and its cavers.

See https://geb.ffspeleo.fr/

Grotte de Clamouse (Hérault)
Ph. Philippe Crochet

## LEGAL STATUS OF CAVES AND PROTECTION RULES

In France, the general rule is that the ownership of the soil leads to the ownership of the subsoil (except for minerals which belong to the state). If one prefers: a cave or a portion of a cave belongs to the owner of the surface. An important cave, developed in an agricultural area where the land plot is relatively small, can be legally constituted of several independent elements belonging to differents owners.

As ownership is the right to use and abuse a property, the owner can, at his discretion, allow free access to everyone (open ownership), authorize entry to certain people (tacit or written agreement with a club or the FFS) or prohibit it completely. He can freely transform the site (tourist development, wine cellar, mushroom farm...), exploit it or destroy it (it is frequent for careers or mines).

There are some exceptions:

- The subsoil can be sold separately from the surface, this is the case for some caves like Bramabiau.
- If the cave is home to protected species, in particular chiropterans, whose disturbance constitutes an offence, there are generally periods of access and periods of prohibition.
- Any archaeological excavation must be authorized by the SRA (Regional Archaeological Service) and the caves with important archaeological deposits are often closed by a door or a grid.
- Some particularly interesting caves have been classified as natural, biological or geological reserves or included in a protected area and their access is subject to specific regulations: visits limited in frequency and number of participants (Orgnac II and III, TM 71).
- It is prohibited to destroy, alter or degrade sites of geological interest, including natural or artificial underground caves, and to remove, destroy or degrade fossils, minerals and concretions present on these sites.

There is no specific legislation covering the protection of caves but some general laws can be used, in Environment

Note: The notion of enclosed property which naturally leads to a right of passage (servitude) on the surface does not apply to the basement: the owner of a beautiful chamber cannot oblige the neighbor who has the entrance to let him circulate in the part of the cave which allows access to this chamber. He has the right to close the cave at the limit of his property but only from his house (Grotte des Canalettes).

Code, Heritage Code and Penal Code.

1) The first law was the Martel Law, in 1902. This law prohibited to throw animal corpses and putrescible waste in caves. It was later repealed and replaced by other more complete laws.
2) The law of 1913 deals with historical monuments and allows to take in consideration prehistoric, historic and artistic remains.
3) The law of 1930 allows to protect natural monuments, or sites if they present characteristics from an artistic, historical, scientific, legendary or picturesque point of view. applies to lakes, waterfalls, peat bogs and coastal dunes, as well as to caves.
4) The law of 1941, validated by the ordinance of 1947, relates to the regulation of archaeological excavations.
5) The law of 1976, dedicated to Nature Conservation takes in account the preservation of biotopes and noticeable geomorphologic or speleologic geological formations and the preservation of sites which have an exceptional interest for studies on life evolution and first human activities.
6) The law of 1980 relates to the protection of public collections against malicious acts.
7) The law of 1994 relates to the protection of the archaeological heritage.

So a cave with concretions and parietal art can be protected as a site (law of 1930), natural reserve (law of 1976), historical monument (law of 1913) and archaeological ground (law of 1941 and 1980).

In 2021, 296 cavities are thus protected on the French territory mainly for the conservation of cave dwelling chiropterans, 270 under the legislation on listed or classified sites (natural sites and historical monuments), 22 under an Arrêté Préfectoral de Protection de Biotope (APPB) and 4 as nature reserves.

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https://www.culture.gouv.fr/Sites-thematiques/Securite-Surete/Securite-et-surete-des-biens/Surete-du-patrimoine-archeologique

Abîme de Bramabiau (Gard)
Ph. Philippe Crochet

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## RECENT PUBLICATIONS


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- **Marc Faverjon, Philippe Brunet et Bernard Dupré, 2008. "**La Grotte de Saint-Marcel-d'Ardèche". CDS 07.
- **Philippe Audra (dir.), 2010. "**Grottes et karsts de France". Collection Karstologia Mémoires 19, AFK.
- **École française de spéléologie, 2018. "**Manuel technique de spéléologie". FFS, (Lyon– 2018)
- **Bernard Chirol, 2021. "**Ces héroïnes des cavernes, Histoire méconnue des femmes dans les grottes du monde".


## BIG EXPLORATIONS


- **Corentin Queffélec. "**Jusqu'au fond du gouffre: Record du monde à La Pierre-Saint-Martin". Tome 1 1968, tome 2 1978.
- **Georges Marry, 1977. "**Gouffre Berger premier –100 : 20 ans d'exploration".
- **Pierre Rias, 1981. "**-1455 mètres et après?". Collection Aventures extraordinaires.
- **Jean-François Pernette, 1983**. "Rivières sous la Pierre".
- **Bernard Lips, Christophe Ohl et GS Vulcain, 1991**. "Le gouffre de Jean-Bernard -1602 m".
- **Baudoin Lismonde (dir.), 1997. "**La Dent de Crolles et son réseau souterrain". CDS 38.


## OLD BUT IMPORTANT PUBLICATIONS


- **B. Collignon, 1988. "**Spéléologie, approche scientifique".
- **Éric Gilli, 1995. "**La spéléologie, sport ou science".
- **Michel Siffre, 1999**. "La France des grottes et des cavernes"**.**


Grotte de la Castelette (Var)
Ph. Philippe Crochet

# GIBRALTAR

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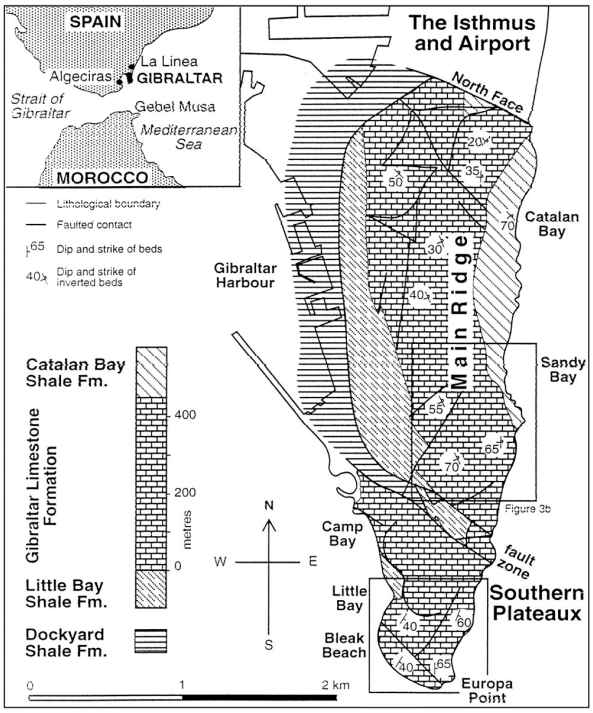
[1]British Caving Association, British Cave Research Association & Fédération Spéléologique Européenne

St. Michael's Cave
Ph. Victor Ferrer

## GENERAL INFO

Gibraltar is a British overseas territory situated on the southerly most tip of the Iberian Peninsula. This small territory is dominated by the iconic 'Rock of Gibraltar' which rises precipitously from the Mediterranean Sea. The Peninsular was initially settled by the Moors from North Africa during the Middle Ages, then taken over by Spain and eventually ceded to the British in 1713 as part of the Treaty of Utrecht. The territory covers an area of just 6.8 square km$^2$ and has a population of 33,701 according to the 2019 census.




The 'Rock of Gibraltar' is a massive promontory of Jurassic dolomitic limestone rising to form a sharp crest which reaches a height of 426 metres above sea level. The promontory is the remnant of a severely eroded and highly deformed faulted limb of a recumbent fold where the oldest strata overlays the youngest. The youngest strata comprise the Catalan Bay Shale Formation and the Little Bay Formation, the oldest the 'Gibraltar Limestone' and the Dockyard Shale Formation. The shales are generally composed of sandstones with successions of limestones, cherts and marls which contain fossil fragments of early Jurassic age (Lias). The Gibraltar Limestone, which comprises the majority of the Rock of Gibraltar is, pale grey to white in appearance and is a finely crystalline, massively bedded, dolomitic limestone. The strata contain fossils which include Brachiopods, Corals, Gastropods and Stromatolites dating back to the Lias epoch 175 to 200 million years ago.

The highly faulted nature of the strata is the result of violent tectonic activity when tectonic plates collided around 5 million years ago. The African plate moved northwards and collided with the Eurasian plate buckling the strata and isolating the Mediterranean area from what is now the Atlantic Ocean. The Mediterranean basin became a shallow temporary

Vanguard's Cave
Ph. Victor Ferrer

lake that over time evaporated to form a shallow basin. The gathering force of the Atlantic Ocean then breached the 'Straits of Gibraltar' on a scale of biblical proportions, flooding the formerly enclosed basin and thus the Mediterranean Sea was born.

Today the promontory stretches out into the Straits of Gibraltar from the Southern tip of mainland Spain and is connected to the continent only by a narrow isthmus of deposited sands elevated just 3m above sea level and 800m in length. This isthmus, of Quaternary age is a tombolo formed by the process of longshore drift.

## KARST AREAS

The karst that makes up the majority of the Rock of Gibraltar contains many caves. The Gibraltar limestone is extensively fractured by minor faults and joints and processes of chemical erosion accelerated by water infiltration, changing climates and sea level fluctuation has provided ideal conditions for speleogenisis to take place over hundreds and thousands of years. The caves are mostly of phreatic origin, with passages enlarged along fault lines. Today there are no surface streams on the promontory so the caves with higher entrances are no longer subject to allogenic recharge.

## NUMBER OF REGISTERED CAVES: : 214 (INCLUDING THE MARINE CAVES)

## DEEPER CAVE AND BIGGER CAVE

Whilst Gibraltar caves are not notable for their depth compared to many other countries that encompass the Mediterranean, many have fine galleries, chambers, spectacular speleothems and intriguing military conversions and installations. The much-celebrated St. Michael's Cave has a total of 24 km of passages and legend has it that it provided a subterra-

St. Michael's Cave
Ph. Victor Ferrer

Gorham's Cave
Ph. Stewart Finlayson

nean access tunnel under the straits of Gibraltar to North Africa. Today St. Michael's Cave is a popular tourist attraction which houses a large auditorium with good acoustic qualities. The cave is 62 metres deep with different levels. The lower series is formed along a large fault with a considerable vertical downthrow and connects with an even lower series where stream action would have played an appreciable part in the cave passage development.

Crystal Cave, however, records the largest natural chamber in Gibraltar.

## ARTIFICIAL CAVES

However, the caves today are inextricably linked to Gibraltar's history as a defensive bastion situated in an important strategic sea passage between two continents. Many tunnels were excavated by the military to link the increase access and use of natural cavities for defensive reasons. Beefsteak cave for example was used as barracks for soldiers, Glen Rocky Cave for war time shelter, Ragged Staff Cave for potential water storage and St. Michael's Cave a makeshift underground hospital. Evidence of Neanderthal existence has been found in a number of locations in Gibraltar. As early as 1848 a woman's skull was discovered in Forbe's Quarry on the north side of the rock. Archaeological excavations in Gorham's Cave on the eastern side revealed further evidence of Neanderthal occupation. A wide variety of animal and plant remains has provided a fascinating insight into the varied diet of the Neanderthals. Neanderthal engravings are clearly visible in Gorham's Cave wall and a wide variety of ancient tools and species of animal bones are on display in the Gibraltar Museum.

## NATIONAL CAVING ORGANIZATIONS

The Gibraltar National Museum Caving Unit (GMCU) is an integral part of the Gibraltar National Museum's Cave Research Project which was established in 2011. Considerable work had already been undertaken since 1989 supporting and instigating archaeological excavations of sites. The GMCU's members are mostly volunteers and skilled in cave exploration, surveying and play a crucial part in cave protection and conservation. The GMCU is a registered member of

the British Cave Association (BCA) and the British Cave Research Association (BCRA).

## SPELEOLOGISTS: 8

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 1

## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLISHING:

- GMCU publications

## REFERENCE RESEARCH BODIES FOR CAVES AND KARST:

- GMCU
- BCRA.

## BIOSPELEOLOGY

The GMCU works closely alongside the Gibraltar Ornithological and Natural History Society (GOHNS) who together prioritise, protect and research cave dwelling species. There are protected bat species and crustacea have been found in pools in Ragged Staff Cave and elsewhere.

## LEGAL STATUS OF THE CAVES AND PROTECTION RULE

The eastern side of the Rock of Gibraltar where there is evidence of Neanderthal occupation in Gorham's Cave and its buffer zone are given legal protection by Gibraltar Heritage Trust Act (1989), the Nature Protection Act (1991) the Town Planning Act (1999), the Town Planning (Environment Impact Assessment) Regulations (2000), and the Nature Conservation Area (Upper Rock) Designation Order (2013). The individual caves containing evidence of Neanderthal and early modern human occupation are protected as Schedule 1 Category A (maximum protection) sites under the Gibraltar Heritage Trust Ordinance.

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Ghoram's Cave
Ph. Victor Ferrer

# GREECE

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**Collaborators: Christos Pennos, Kaloust Paragamian, Vasilis Gerovasileiou**
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Oktonia, Euboea
Ph.Theodosiadis Thomas

## KARST AREAS

Carbonate rocks (limestone, marbles and dolomites) outcrop in Greece to a great extent. This almost uniform geological composition of the bedrock, in combination with the very active tectonic regime and the climatic setting of the broader region of the east Mediterranean, favours cave development (Pennos and Lauritzen, 2013).

The Greek peninsula exhibits a complex geological history, but a relatively homogenous lithological composition, as it consists mainly of carbonate rocks (marble, limestone, and dolomite). In general, the northern and northeastern part of the country consists of Paleozoic marbles and metamorphic rocks that are part of the old continental crust, and in the periphery of which the closing of the Tethys Sea took place during the Alpine orogenesis. In contrast, the rest of the Greek mainland, as well as most of the islands (apart from those that belong to the Hellenic arc and demonstrate considerable volcanic activity), are mainly built up of Mesozoic limestones and igneous rock for-

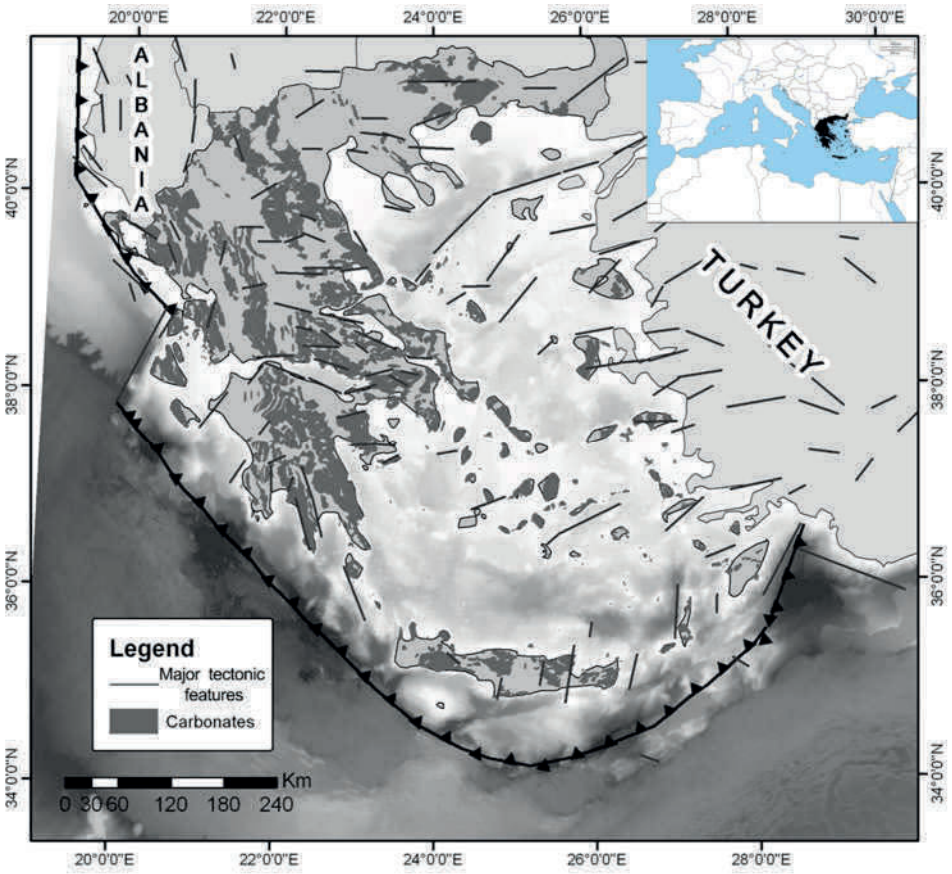



Fig.1 Main carbonate areas in Greece (modified from Pennos et al., 2018)


Latsida, Lasithi
Ph. Efchetzis Manos

mations. The carboniferous sediments represent shallow and deep marine deposits from the Tethys Sea.

Overall, the general structure of Greece is characterized by a series of stacked nappes, with a composite thickness of ~5 –10 km, consisting of the upper crust that was detached from the present subducted continental and oceanic lithosphere of the Adriatic-African Plate (Jolivet and Brun, 2010; van Hinsbergen et al., 2010; van Hinsbergen et al., 2005). These nappes (or “mega-units”) were thrusted and stacked in an east-to-west direction since the Cretaceous (Faccenna et al., 2003; Jolivet and Brun, 2010; van Hinsbergen et al., 2005) and form a shortened representation of the paleogeographical distribution of continental ribbons and deep basins that existed in the western Neo-Tethys (e.g., Dercourt et al., 1986; Mountrakis, 2010; Stampfli and Hochard, 2009).The Aegean Sea and its surrounding areas belong to the active continental boundary of the Alpine-Himalayan belt (Fig. 1) and are subjected to large-scale active deformation that stems from the subduction of the eastern Mediterranean lithosphere under the Aegean Sea, along the Hellenic

Eptastomo, Parnassos
Ph. Nikolaidis Stefanos

Arc (Papazachos and Comninakis, 1971). Consequently, most continental and coastal parts of Greece share common characteristics of back-arc extensional tectonics, expressed by the presence of a strong deformational pattern, volcanic activity, and the development of fault bounded grabens, lying in accordance with the dominant North to South extensional stress field. However, as illustrated in Fig.1, the northern part of Greece is additionally influenced by a subsidiary right-lateral shear because of its co-existence with the North Aegean Trough, a dextral strike-slip structure (McKenzie, 1972).

Two areas that present high density in caves are the Pindus mountain that runs down the Greek peninsula from North to South and the Lefka Ori mountain range in the western Crete. These two areas exhibit similar geological characteristics that rank them amount the most densely karstified areas of the world (Adamopoulos, 2013). In detail, both areas are built-up of thick (>2000 m) fine-layered carbonate deposits, limestone and dolomite. They are highly fractured due to their vicinity to the Aegean Arc (see Fig. 1) and receive great amounts of precipitation sourcing from the Mediterranean Sea (Pennos et al., 2018). This setting enables the development of a deep vadose zone that results in the development of deep caves (e.g. Hasma Epous and Provatina in Pindus mountain and Gourgouthakas and Lion Cave in Lefka Ori, Crete Island).

## NUMBER OF REGISTERED CAVES: >10,000

**Longest caves**

| Name | Length (m) |
|---|---|
| Aggitis Cave-Maaras | >11,700 |
| Diros Cave Vlychada | >10,000 |
| Ano Peristeras | >8,000 |

Maaras, Drama
Ph. Nikolaidis Stefanos

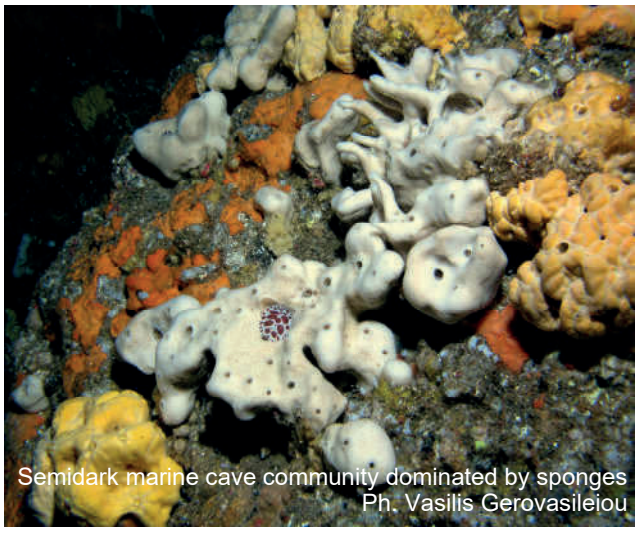
**Deepest caves**

| Name | Depth (m) |
|---|---|
| Gourgouthakas | -1,208 |
| Cave of the Lion (LOC21) | -1,110 |
| Tafkoura | -860 |
| Peleta | -620 |
| Pralina | -617 |

White Mountains, Chania
Ph. Mazonakis Giorgos

Semi-submerged marine caves in the Ionian Sea
Ph. Vasilis Gerovasileiou

## MARINE CAVES: ~1,000



Semidark marine cave community dominated by sponges
Ph. Vasilis Gerovasileiou

Marine caves constitute a typical feature of the Greek rocky coastline. Approximately 1,000 marine caves (~700 in the Aegean and ~300 in the Ionian Sea), either semi - or fully submerged, have been recorded in Greece so far (Giakoumi et al., 2013; Sini et al., 2017). Most records correspond to shallow and/or semi-submerged caves which are easier to spot and access by both scientists and recreational divers. Most marine caves are located in the island-dominated South Aegean Sea (e.g. Cyclades and Dodecanese Islands), the Northern Sporades Islands in the North Aegean, and the Ionian Islands, where carbonate coasts prevail. Nevertheless, given the complexity of the Greek coastline and the logistic constraints involved in finding marine caves, their number is assumed to be much higher. Marine caves are widely acknowledged as “biodiversity reservoirs”, harbouring several rare and protected species (Gerovasileiou & Voultsiadou, 2012; Gerovasileiou & Bianchi, 2021). Due to their exceptional biological wealth marine caves are protected at the European (92/43/EEC) and Mediterranean levels (Barcelona Convention). Despite the high number of marine caves in Greece, only few have been systematically studied for their biodiversity. The exploration of approximately 40 marine caves and cave systems of Greece during the last decade brough to light ~600 taxa, including new additions to the regional fauna and new species for science (Gerovasileiou et al., 2015). Nevertheless, there are still important gaps of knowledge regarding particular coastal and insular areas of Greece, cave types (e.g. anchialine caves) and taxa, highlighting the need for future research, mapping efforts, monitoring and conservation initiatives.

| Marine / Anchialine caves | | |
|---|---|---|
| **Name** | **Length (m)** | **Depth (m)** |
| Vouliagmenis cave | >3,000 | >80 |
| Sintzi cave | >1,500 | -150 |

Provatina, Ioannina
Ph. Nikolaidis Stefanos

## ARTIFICIAL CAVES

There are more than 500 artificial caves and networks of underground galleries, mostly ancient quarries, mines and underground aqua-ducts. The most extensive network of mining galleries is located in Lavrion (Attiki). Its aggregated length is several hundreds of kilometers in six levels, interconnected with a multitude of shafts (Economopoulos 1996, Perifer-akis et al. 2019).

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST:

- Ephorate of Paleoanthropology and Speleology

https://www.culture.gov.gr/en/ministry/SitePages/viewyphresia.aspx?iID=1784

- Hellenic Institute of Speleological Research (HISR) https://inspee.gr/

## NUMBER OF SPELEOLOGİSTS: ~500

## NUMBER OF SPELEOLOGİCAL GROUPS AND ORGANİZATİONS: ~20

**NATIONAL FEDERATION:** Hellenic Federation of Speleology (F.H.S), www.fhs.gr

**OLDEST CAVING CLUB:** Hellenic Speleological Society (H.S.S), https://ese.edu.gr/

**NATIONAL MAGAZINE**: The Hellenic Speleological Society issued a Bulletin from 1951 till 2000

## MAIN SPELEOLOGICAL PUBLICATIONS:

- The Caves of Greece (by Anna Petrocheilou)
- Several books about caves for each geographical area of Greece

## BIOSPELOLOGY

The Cave Fauna of Greece database currently holds data on more than 880 species and more than 540 caves from all 14 administrative regions. It also holds 110 taxa identified to generic level but these are visible only in the species lists for each cave. The census includes a total number of nearly 3,000 records.

Kriti (Crete) is the most studied Region of Greece (34% of the caves). Insular Regions (North & South Aegean, Ionian Islands, and Crete) host a remarkable percentage of endemic and troglobiont species.

There are 883 species in 442 genera, 194 families, 64 orders, 20 classes, and 6 phyla. The most diverse Classes are Arachnida (29.7%) [Araneae 16.5%] and Insecta (Ectognatha) (29.2%).

Geoffroy's bat, *Myotis emarginatus*
(E. Geoffroy Saint-Hilaire, 1806)
Ph. Paragamian Kaloust / HISR

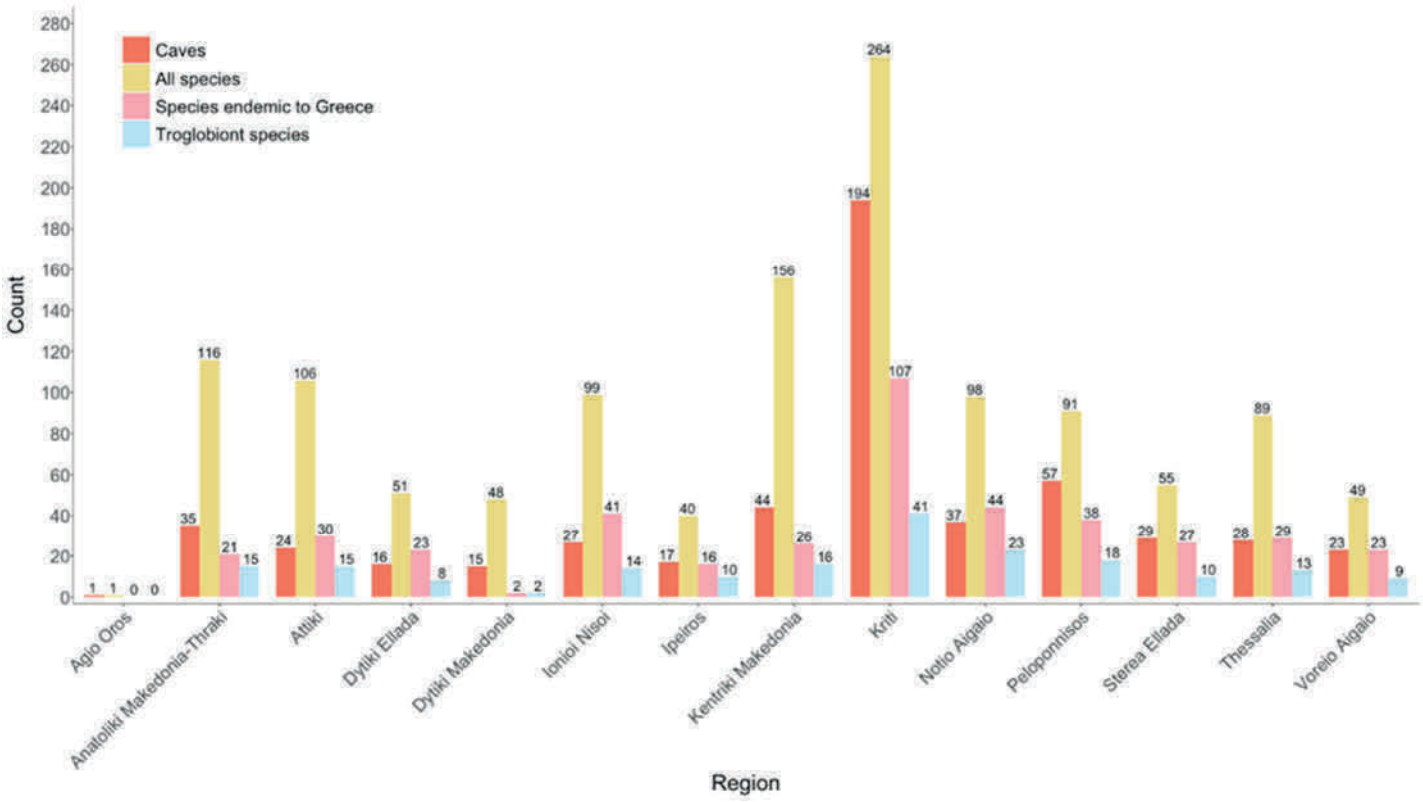
Troglobitic amphipod,
*Exniphargus tzanisi* Karaman G.S., 2016
Ph. Paragamian Kaloust / HISR

Troglobitic dipluran, *Plusiocampa hoffmanni*
Sendra & Paragamian 2019
Ph. Paragamian Kaloust / HISR

Korykeio Antro (Parnassos Mt.) is the cave from where the first cave animals of Greece have been recorded. From the samples collected by Theobald Johannes Krüper (1829–1917), Brunner Von Wattenwyl (1861) identified the cave cricket *Rhaphidophora cavicola* - a record assigned recently to *Troglophilus zoia* (Di Russo et al., 2014) - and Schaum (1962) described a new ground-beetle species (*Anophthalmus krueperi* = *Duvalius krueperi*), the first obligate cave-dwelling species recorded in Greece. Since then, the speleobiological research in Greece revealed an interesting fauna of more than 880 species from more than 540 caves. More than 335 of them were described for the first time.

Nearly half of the species of the cave fauna of Greece are Greek endemics. Obligate cavernicolous species (troglobionts/stygobionts) represent 22.3% of the cave fauna and the vast majority are steno-endemic. Only 12 species are not endemic to Greece.

The majority of the species found in the caves of Greece have not been evaluated for the IUCN Red List (84.9%) nor for the GR Red Data Book (85.9%). The adequately evaluated groups are bats, orthopterans, and mollusks. Only 9 out of the 192 obligate cavernicolous species have been evaluated.




## LEGAL STATUS OF CAVES AND PROTECTION RULES

Only 7% of the cavernicolous species (mostly Dolichopoda cave crickets and Bats) are protected according to the European and the National legal framework! No obligate cavernicolous species are legally protected.

Only 20 caves are protected by name under the Greek environmental legislation. About 305 (55.2%) of the caves cited in the CFG database are situated within Natura 2000 sites (Sci's and/or SPA's). In addition, 69 caves (12.3 %) are situated within Wildlife Refuges.

According to the Greek Archaeological Law, all caves associated with ancient human uses are considered protected.

## ESSENTIAL COUNTRY BIBLIOGRAPHY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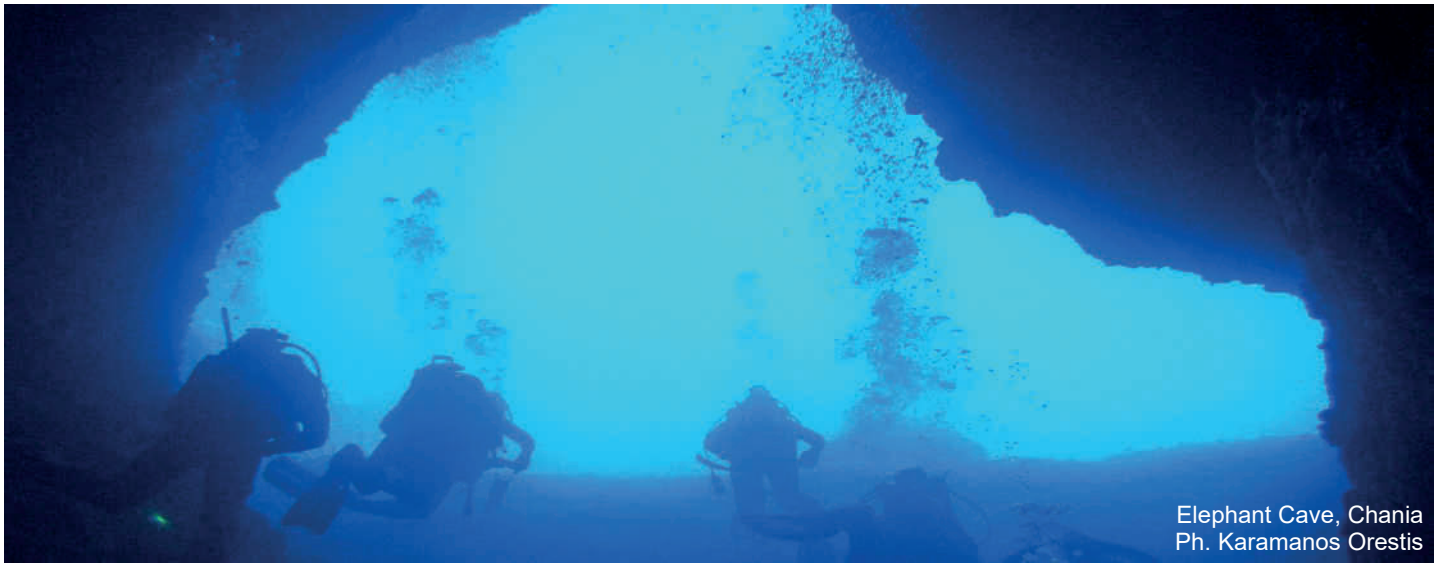

Elephant Cave, Chania
Ph. Karamanos Orestis


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# ISRAEL

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Collapse hall in Kemah cave, Piping cave in the Dead Sea basin
Ph. Boaz Langford

## GENERAL INFO

In Israel (area ~20,000 km²), most hilly areas are of speleological interest, characterized by many types of rocks that favour the formation of natural and artificial caves. Israel displays a gradient of active karst and cave features from the intensive karstification of Lebanon in the north to less karst in Eilat region at the southern Negev desert.

This is attributed mainly to the climatological gradient from Alpine-Mediterranean climate in the Lebanon - Hermon mountains in the north, with precipitation >1000 mm/year, to the extremely arid southern Negev, with <50 mm/year. Another factor is the southward decrease in carbonates/clastics ratio of the phanerozoic stratigraphic section, due to the increasing distance from the Tethys Sea which deposited significant amounts of carbonates.

Carbonate rocks outcrop in some 75% of the hilly regions of Israel. They are predominantly of Jurassic to Eocene age. However, much of the carbonates contain marls which inhibit extensive karst development, promoting the dominance of fluviokarst features. Another inhibiting factor is the abundance of faults in the Hermon, Galil and Shomron regions. The faults are thought to constrain the temporal and spatial continuous underground flow, limiting the development of large caves in these regions.

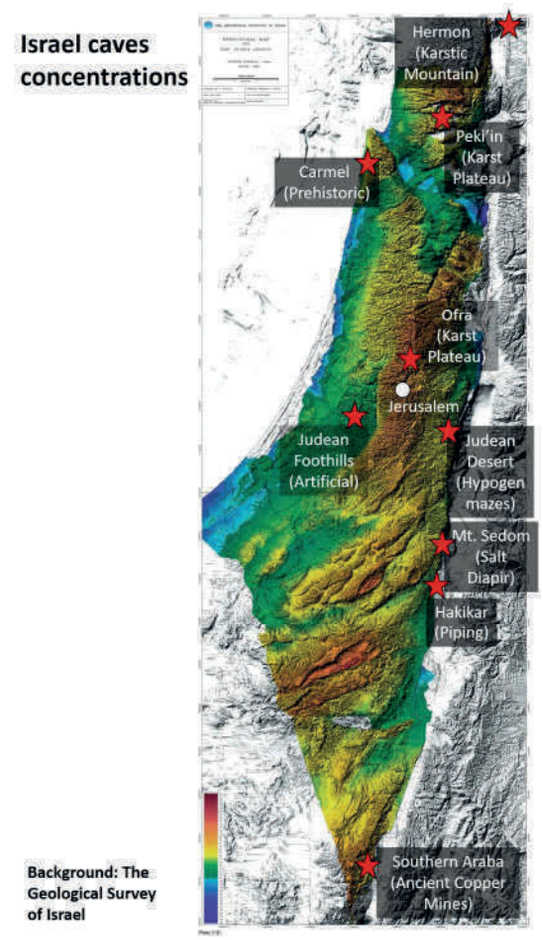
Most large limestone caves of Israel are relict hypogenic voids, which do not show any relation to subaerial topography. Today these caves are either dry or experience vadose dripwater. Some of them have been sealed from the surface until opened by erosion or recent construction activity. They may contain valuable paleoclimatic records.

Vadose caves are also common in central and northern Israel, and typically experience some water flow and active dissolution during the wetter winter-spring seasons. These are mostly composed of vertical shafts with few horizontal sections.

The unique rock salt karst of Mount Sedom exhibits the largest salt caves known in the world.

Some sea caves, attributed mainly to wave action with limited dissolution appear in chalk and 'Kurkar' sandstone ridge along the Mediterranean coast.

Israel is especially rich in artficial (man-made) cavities of many types.



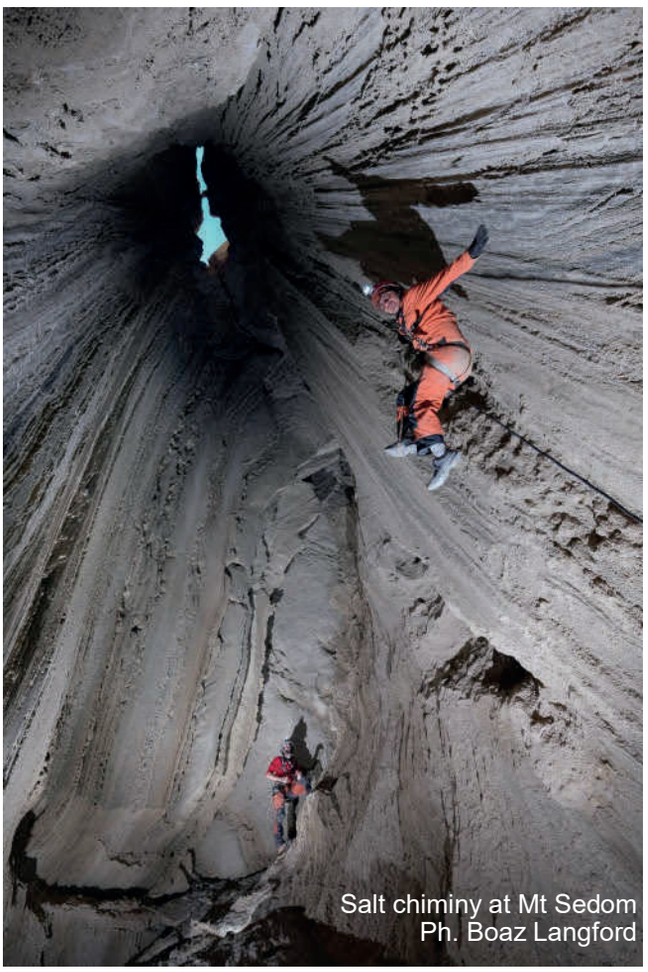

## KARST AREAS

The major karst and caves regions of Israel are briefly reviewed below.


Kemah cave, Piping cave in the Dead Sea basin
Ph. Boaz Langford

**Hermon and Golan**

The higher part of Mount Hermon, on the northern end of Israel, displays distinctive alpine karst features. The elevation within Israel reaches 2,220 meters, and snow covers the higher parts several months a year. Massive Jurassic limestone, several hundred m thick, gives rise to developed holokarst with doline fields. However, the intensively fractured rock limits the number and extent of large and deep caves. Only two caves are known above 2,000 meters above sea level (Me'arat Pitulim and Me'arat Mizpe Shelagim), both vadose and only tens of meters deep and long. The temperature in depth of these caves does not exceed a few degrees C even in summer, so they form a unique ecosystem in Israel. Known caves at lower elevations on Mount Hermon flanks are not larger than tens of meters too, but they include phreatic features, indicating longer evolution period.



Salt chiminy at Mt Sedom
Ph. Boaz Langford

The basaltic Golan Plateau, south of Mount Hermon, exhibits some pseudokarst features and some basaltic caves, but no lava tubes are known.

**Galillee**

The Galillee (Galil) mountains is the major karst region of northern Israel, developed on Cretaceous to Eocene carbonates. Mediterranean fluviokarst is developed across the whole region, while the upper Galil, especially around Mount Meron, displays some mature karstified areas, with abundant vadose caves. Of these, Mount Peqi'in is notable for its developed doline karst landforms with highest density of limestone vadose shafts in Israel. Two ponors drain relatively large karst areas: Me'arat Pa'ar, in the bottom of a large doline, and Zomet Meron sink. Some of the largest caves of the Galil are (1) Rahav Cave (Israel's deepest); (2) Me'arat Alma - a tectonic cave altered by phreatic dissolution; (3) Me'arat Jermak - a vertical vadose shaft system; (4) Me'arat Berenice - a relict phreatic maze.

Diving is needed to explore some Galil caves. Me'arat En Nur (spring of Tabgha) is an underwater resurgence cave on

Salt stalactites in Malham cave, The longest salt cave in the world
Ph. Boaz Langford

With more than 200m this is the largest corridor in Israel, Judean desert
Ph. Boaz Langford

the northwest coast of Yam Kinneret. Other short spring caves with perennial flow are Enot Enan, En Tamir and En Amal. Sea caves with dissolution features are developed in Rosh-Hanikra.

**Mount Carmel**

The Carmel ridge is built mainly of Upper Cretaceous carbonates.

Fluviokarst is common, while karstic closed depressions are rare. A major active fault along the north-eastern edge of the ridge seems to inhibit karst development on this side. Relict phreatic caves are common mainly along the western border of the ridge, commonly with prehistoric remains, while vadose caves are less common. The longest cave is Me'arat Ornit - a dry hypogene maze.

**Shomron**

Most karst landforms in Shomron appear on Cretaceous to Eocene limestone and dolomite. Western Shomron is rich in small caves with relict phreatic and active vadose features. A large cave is Me'arat Nahal Qana - a tectonic maze with a phreatic chamber.

The Ram'alla anticline at eastern Shomron is poor in large caves in its northern part, where it is dissected by large transversal faults. However, large caves do appear on its southern part, which is structurally similar to the Judean mountains. Of special interest is Nahal Delaya, where three large caves are grouped together.

Few caves are known across the Eocene carbonates of the northern Shomron syncline, although it serves as a major karst aquifer of Bet-She'an valley and Shekhem region.

Aragonite and Gypsum in Izim cave, small hypogenic cave in the Negev desert
Ph. Boaz Langford

The limited outcrop of Jurassic limestone displays extensive karren features, with few small caves. Karst landforms and caves appear rarely in Neogene conglomerates of eastern Shomron.

**Judea**

Karst features appear here on Cretaceous to Eocene carbonates. Much of the upper erosion surface of Judean Mountains was formed by karst denudation. Fluviokarst is most common, but north of Jerusalem there are some areas of inter-

nal karst drainage, including a doline field with 45 known caves, mostly vadose shaft systems. Lack of major faults has promoted the development of long and stable subsurface flow routes in the confined zone of Judea, allowing the development of the largest and most abundant limestone caves in Israel. The known hypogene caves are mostly relict, sometimes forming two to three dimensional mazes, such as Me'arat Hariton - the longest limestone cave in Israel, with some 4 km of mapped passages. Most large caves appear in massive Turonian limestone along the eastern monoclines of Hebron-Ramalla anticline. The most studied cave in terms of speleothems in Israel is Me'arat Soreq. This show cave is richly decorated with speleothems.

Natural caves in chalk are relatively rare. The longest is Me'arat Niqbot Hamaim in the Eocene chalk of the Judean Foothills. The largest limestone chamber in Israel (~200x100 m) is Me'arat Atarot, in northern Jerusalem.

A chamber cave in flintstone, Negev desert
Ph. Boaz Langford

**Judea - Negev deserts**

This region is arid, with <200 mm rain/year. Therefore active karst processes are mostly limited to the micro scale.

The Judean desert is a rain-shadow desert, located east of the Judean mountains. The mountains (precipitation of up to 600 mm/year) are the input zone of groundwater discharging along the Dead Sea. Such circulation could take part in forming the relict hypogenic caves found in Turonian limestone west of the Dead Sea.

Unlike the Judean desert, the Negev desert is part of the global Saharan arid belt. Large caves are relatively rare, although carbonate rocks are common. Water was probably insufficient for karst development even during humid phases of the Pleistocene. The largest caves are Marzeva and Ashalim, relict hypogenic systems in Cretaceous carbonates. Small caves in Ma'ale Hameshar are attributed to deep hypogenic waters rising along faults. Karstic caves are less common in the extremely arid southern Negev.

The Dead Sea rift valley boasts many long piping caves in the Lisan Formation marls, some of which are among the largest known globally.

**Mount Sedom**

Mount Sedom salt diapir is extensively karstified in spite of its extremely arid climate, due to the high solubility of rock-salt. Some 200 caves have been studied, all of which developed during the Holocene. The caves are mostly branchwork

vadose canyons. The downcutting rates in the salt caves are some of the most rapid in karst. Me'arat Malham is the longest salt cave known in the world, with over 10 km of mapped passages. Some other caves, longer than 200 m are: Me'arat Sedom, Colonel, Dorban, Zekhukhit, Liquid Crystal, Italkit, Bua, Dud, Zaqif, Ionim, Karbolot, Lehavim, Lashleshet, Mifgash, Mifratsim, Mirpeset, Notsa, Nahash, Sedeq, Falafel, Parsafonim, Peteq, Tsinor, Qolno'a, and Qupa.

Striped hyena activity in the Hyena cave, Negev desert
Ph. Boaz Langford

## NUMBER OF REGISTERED CAVES:~6,000

**Most important longest caves**

| Name | Length (m) | Depth (m) | Rock type |
|---|---|---|---|
| Malham | 10,005 | -126 | salt |
| Hariton | 4,205 | -15.5 | limestone |
| Ayyalon | 2,700 | -31 | limestone |
| Colonel | 2,500 | -102.5 | salt |
| 'A'rak Na'asane | 2,238 | -61 | limestone |
| Sedom | 1,799 | -85 | salt |
| Qina | 1,411 | -85 | limestone |
| Hakikar | 1,392 | -37.5 | marlstone |
| Marzeva | 1,241 | -19 | limestone |
| Sela' | 1,200 | -14.5 | limestone |

**Most important deepest caves**

| Name | Depth (m) | Rock type |
|---|---|---|
| Rahav | -187 | limestone |
| Huta Jermak | -157 | limestone |
| Tzav | -151 | limestone |
| Tumuli | -140 | limestone |
| Krashim | -137 | limestone |
| Sakana | -136 | limestone |
| Sivan | -136 | limestone |
| Malham | -127 | salt |
| Tzedek | -126 | limestone |
| Pritza | -125 | limestone |

## MARINE CAVES: ~20

Most marine caves are in Cenomainan chalk at Rosh-Hanikra ridge, at the northernmost coast of Israel. These are impressive caves combining karst and reshaping by waves. The major ones are operated as show caves.

Smaller marine caves are found in Pleistocene sandstone (locally termed Kurkar) ridges, where they are close to the coastline.

| Most important marine caves | | |
|---|---|---|
| **Name** | **Length (m)** | **Depth (m)** |
| Rosh Hanikra | ~100 | ~-15 |
| Eemian | ~10 | -8 |

## ARTIFICIAL CAVES: ~3,000

Throughout ancient Israel, and especially in the Judean Foothills, rock-cut underground chambers were created in antiquity, as a part of the economic and physical infrastructure of towns and villages. This description is focusing on the area of Judean Foothills and use it as example for the artificial cavities in Israel.

This area, located west of the Jerusalem and Hebron hills, is characterized by Eocene chalk. The largest number of cavities is found on chalks of the Zor'a formation, Maresha member. The thickness of Maresha member varies between 30 m to 100 m, and it is usually covered by a 1 - 3 m of lime-crust, locally known as *Nari*.

Chalcolithic remains from Nahal Qina cave, northen Negev desert
Ph. Boaz Langford

Through the relatively easy process of cutting the soft chalk, various artificial subterranean chambers were carved during the antiquity. These include cisterns, rock quarries, olive press, stables, columbaria, storerooms and granaries, ritual immersion baths (Jewish *miqvaot*), cut underneath houses and courtyards. Rock-cut tomb chambers surrounded ancient settlements. The quarrying process produced good quality blocks of chalk, used for building houses above ground.

It is difficult to establish the exact chronology of each and every cavity, but it seems that the earliest underground chambers were created during the Bronze and Iron Ages. The hewing technique was refined in the Hellenistic and early Roman periods. The results can be seen in their full magnificence at the Hellenistic city of Maresha (mostly 3rd and 2nd centuries BCE).

Underneath hundreds of sites throughout the Judean Foothills, man-made underground facilities and features were intentionally put out of use when they were interconnected to form ramified complexes with narrow, winding burrows, on several levels. The fact that the owners of these rock-cut features were ready to eliminate their own subterranean infrastructure, attest to an increasing concern for survival during times of distress. Many of these complexes contained data-

| Most important artificial caves | | |
|---|---|---|
| **Name** | **Cave Type** | **Date** |
| Bet Govrin | Bell-shaped quarries | 4th -8th century CE |
| Zedekiah's Cave | Quarry | ~50 BCE to 1907 |
| Siloam tunnel | Water supply | 8th - 7th century BCE |
| Qumran Caves | Archiving storage | 3rd-1st century BCE |
| Timna Mines | Copper mine | 5th millennium BCE to recent |
| Beit She'arim | Necropolis | 1st-2nd century BCE |

ble material, establishing their main period of use to the Second Jewish Revolt against the Romans. One of the characteristics of this revolt, known also as the Bar Kokhba Revolt (132-136 CE), is the extensive use of underground cavities for hiding, escape and refuge purposes.

Most of the hiding complexes were hewn artificially under or near residential buildings in ancient settlements. They include a maze of rock-cut chambers connected to each other by low and narrow passages, known also as burrows. Passage through the burrows requires one to kneel down, crawl and sometimes even to creep. The burrows are the typical featu-

re that identifies a rock-cut system of underground cavities as a hiding complex. The openings into chambers are always small and low, and require one to kneel down in order to enter. Many rooms, storerooms, halls and burrows could be sealed from the inside. Thus, the complexes were designed so that the occupants could defend themselves from within, against an enemy attempting to enter.

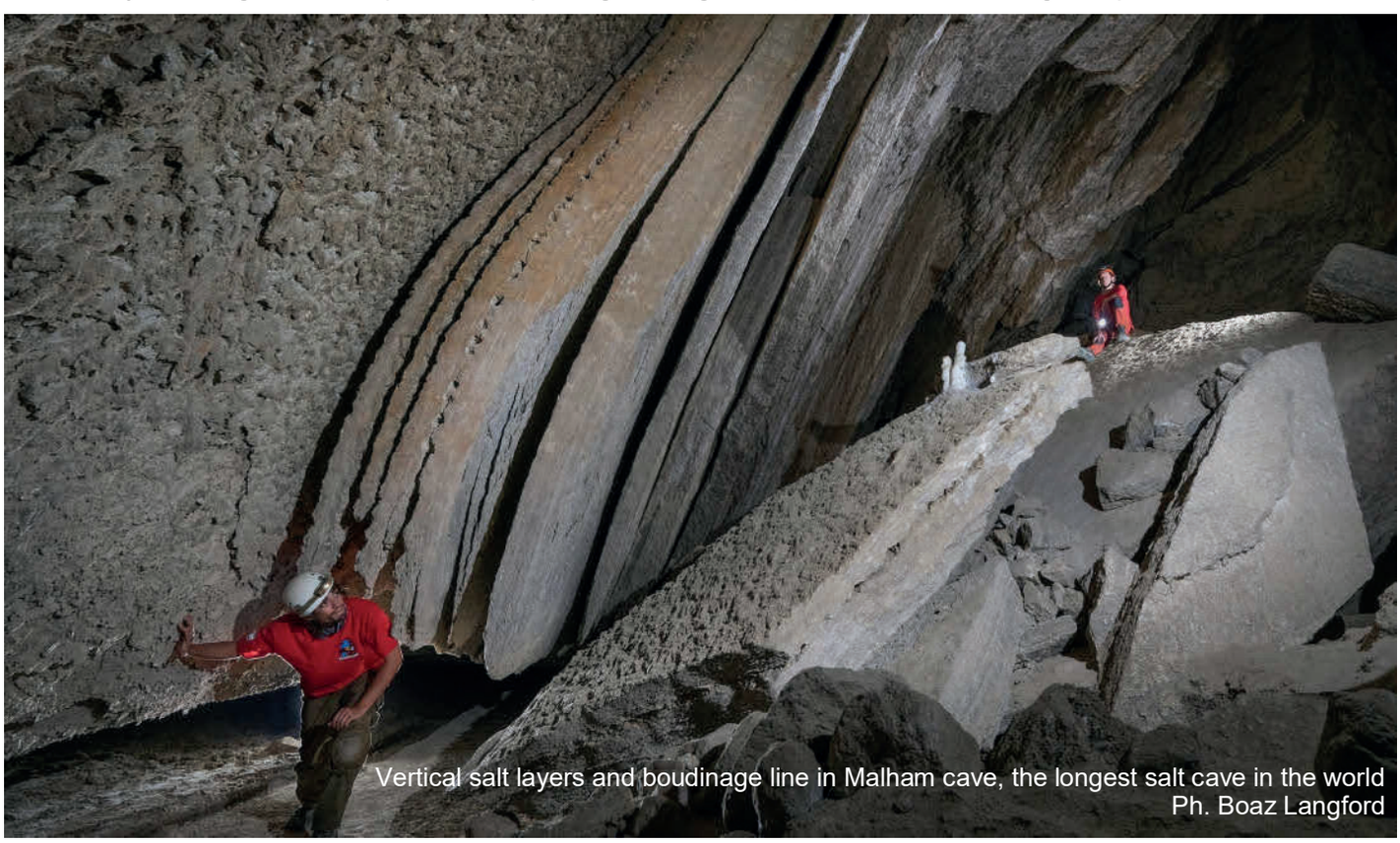
The narrow entrances to rooms and burrows were blocked, or cut off with various kinds of locks, such as a rectangular stone slab the same size as the burrow, a large round stone the size of the average opening, beams and bars. Some sealing stones were found in the burrows or in the shafts; in other cases, their existence is indicated by niches cut in the walls, which held bolts and beams in their place.

A fascinating phenomenon, common in the Judean Foothills, are the “bell-shaped” underground cavities (or quarries). The first stage of making a bell-shaped cavity was to cut a rounded opening in the upper *Nari* crust. From the opening, a vertical, narrow shaft led to the soft chalk below. Upon reaching the soft chalk layer, the carvers started widening out the cave downwards and laterally in a circular shape. This method of quarrying created the typical bell-like shape, which formed a large but relatively stable underground cavity. Quarrying the cavities produced large underground spaces and clusters thereof – the largest are ca. 25 meters deep. After the quarrying was completed, many underground quarries were converted for a variety of uses; some were transformed into dovecotes (known also as *columbaria*). Many dovecotes, rather impressive, contain hundreds of pigeon niches in neatly arranged rows. Other cavities were converted into underground olive presses. Few cavities, usually of smaller dimensions, were converted into water cisterns. Other were used by squatters for residence or by shepherds as animal pens, by addition of partition walls built of fieldstones.

Most “bell-shaped” quarries are dated to the Byzantine (ca. 4th to 7th c. CE) and Early Islamic period (ca. 7th – 8th B CE).

Additional clusters of artificial cavities are those of the Galilee and Eilat area. Generally, the Galilee is characterized by the same type of artificial cavities as those of the Judean Foothills. However, a unique type for this area are the Cliff Shelters: numerous hard-to-reach cavities, mostly simple manmade chambers, and some natural karstic caves, which are concentrated in the highest cliffs of the Galilee. Human activity in the cliff shelters is dated to the Hellenistic and Early Roman periods, with evidence for a short episode in the middle Islamic period.

The artificial cavities of Eilat area are copper mines that are associated with mining activity in the region during the Chalcolithic, the Early Roman, and the Early Islamic periods. These mines are among the longest and most developed in the area. They are designed as complex net-like passages and galleries, in some cases having multiple levels.



Vertical salt layers and boudinage line in Malham cave, the longest salt cave in the world
Ph. Boaz Langford

## NATIONAL CAVING ORGANIZATION

Israel Cave Research Centre (ICRC)

## NUMBER OF SPELEOLOGISTS: ~100

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 3

## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLISHING

- *"Niqrot Zurim"* https://www.malham.info/nikrot

## SPELOBIOLOGY

The wide variety of cave types and cave habitat-types in Israel is reflected in the species-assemblage, which is different in each cave type. The cave fauna of Israel reflects the evolutionary history that took place in the epigean vicinity of the caves. The geographical location of Israel, acting as an intercontinental bridge, is represented by the fauna of different continental and biogeographic regions, such as Palearctic, Saharo-Arabian and Afro-tropical cave fauna, as well as endemic species to caves, known only from Israel. The Levant, which experienced major geological events and dramatic climate changes in the last millions of years, enable us to explore the origin of different cave-dwelling organisms and to test the different scenarios of the drivers or 'motivation' of the animals to live in caves. In general, we can define one group of cave-dwelling relict species from a Palearctic origin, while another group can be defined as species of a desertic or tropical relicts. The Palearctic-origin species, represent a northern and temperate relict fauna, populated in humid and cold caves, usually with active karst processes, situated in the Mediterranean region of north and central Israel. For example, the Dwarf Pill Millipede *Trachysphaera* sp. Heller, 1858 (Diplopoda, Glomerida, Glomeridae) or the spider *Hoplopholcus ceccoonii* Kulczyński, 1908 (Arachnida, Araneae, Pholcidae), both are present in relatively cold or humid caves in the Mediterranean region in Israel, representing a northern fauna in the caves. The other group which represents Saharo-Arabian or Afro-tropical fauna, can be found in hot (dry or humid) caves in the deserts of Israel, or even in caves with similar climate characters in the Mediterranean region of Israel. Two arachnids can demonstrate the desertic and Afro-tropical fauna, one is *Haasus naasane* (Aharon et al. 2019), (Arachnida, Opiliones, Laniatores), a small harvestman which lives in hot and humid cave in the Judean desert, representing an Afro-tropical relict, and *Artema nephilit* (Aharon, Huber & Gavish-Regev, 2017), (Arachnida, Araneae, Pholcidae), a large pholcid which prefer hot caves in the arid and semi-arid zone of Israel. In addition to the relict species, there are also evidence of species that may have entered caves in order to exploit available habitats, which led to accumulate adaptive shifts and to speciation. This confluence of relict fauna, known mainly from glacial or cold regions, and active inhabitation of caves, known mainly from tropical regions, may demonstrate the diversity of cave types and habitats in the cave of Israel, that give place to different organisms to establish populations in appropriate niches in the caves. This phenomenon can be observed in caves located not only in different geographical regions in the country, but also in the same geographic region experiencing different ecological factors, as slope face, altitude, and even in different niches in the same cave.

Greater mouse-tailed bat in a Piping cave, Dead Sea
Ph. Boaz Langford

The Ayyalon Cave system combines hypogenic karst with endemic subterranean fauna. The unique faunal assemblage utilizes chemosynthetic food web based upon $H_2S$ within the ascending plumes of hydrothermal water. Molecular evidence suggested that the aquatic system age is > 5.8 Ma. The high endemism of terrestrial troglobites at Ayyalon Cave

indicate longer isolation age, most probably ~14 Ma – the end of the last transgression which inundated the lower Shefela region.

## LEGAL STATUS OF CAVES AND PROTECTION RULES

There is no ‘Cave Conservation Law’ in Israel. Caves are protected through indirect laws such as the 'Declaration of Protected Natural Values', which also refers to stalagmites and stalactites. It is relevant also for all 32 bat species that live in Israel. It means that hunting, collecting or harming bats, as well as damaging their natural habitats (bats roost-caves), is considered an illegal action.

Natural or artificial caves, with evidence for archaeological activity, are protected by the 'Antiquities Law'.

Another statute that indirectly protects caves is the ‘Nature Reserve Regulation’. This document is relevant for cave protection since many caves in Israel are located in nature reserves. These caves have accessibility limits and are protected from visitors, except researches and professional cavers that can visit with a special permit. A visit to a cave within a nature reserve without a permit is possible, however, these caves are limited in number, and have been declared as permissible caves to visit. There is no restriction for visiting caves that are outside a nature reserve, except for the need to protect their 'Protected Natural Values'.

The most significant damage to caves in Israel are those discovered during infrastructure projects, such as: quarrying, tunnelling, road construction, and urban development. Due to the lack of 'Cave Protecting Law', and due to the contractors' preference to avoid a delay in the project, the caves are usually destroyed without reporting to nature conservation organizations and cave researchers.

Salt Cave in Mt Sedom, Dead Sea
Ph. Boaz Langford

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# ITALY

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Zubbia Camilleri (Sicily)
Ph.Victor Ferrer

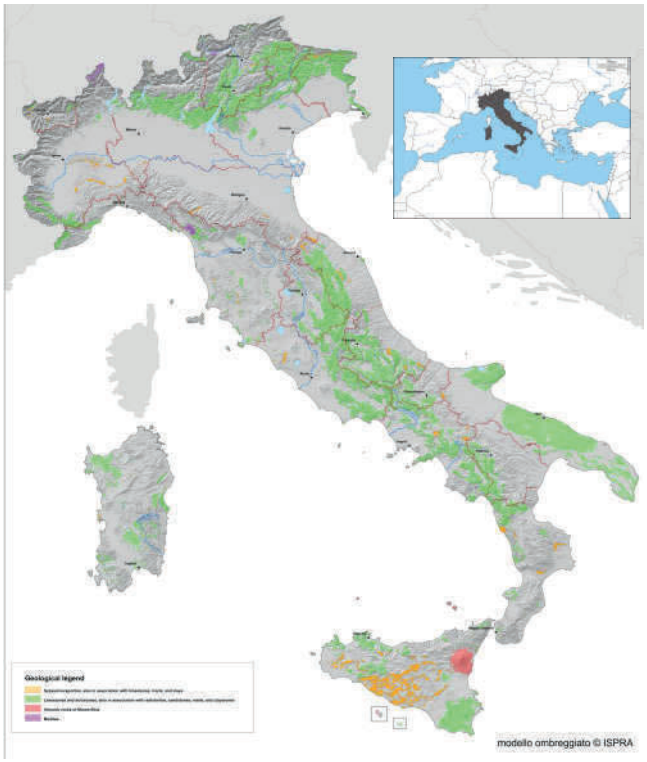
## GENERAL INFO

In Italy (surface area 301,338 km²), areas of speleological interest, characterized by types of rocks that favour the formation of natural cavities, make up about one-sixth of the entire land.

All Italian regions have such areas in their territory, although with significant differences in extension and type of caves.

This feature has spurred speleological explorations in the Italian territory for over a century.

Over more than a century of exploration, more than 40,000 caves have been discovered, explored and documented, mainly in carbonate rocks (limestones and dolomites). There are also numerous caves in gypsum and basaltic lava, as well as in other lithotypes (evaporites).




Map of geological formations of spelological interest

## KARST AREAS

All Italian regions include karst areas, with significant differences in terms of size. In the territory of Emilia Romagna karst covers about 1% of the total area, while in Apulia, thanks to the extensive outcrops of limestone, the value reaches 48%. The extensive karstic areas in Italy have encouraged systematic explorations for more than a century, leading to discovery and documentation of over 40,000 caves.

The main karstic systems are developed in sedimentary carbonate rocks (limestone and dolomite) and metamorphic rocks (marble): the *Monte Canin* complex in Friuli Venezia Giulia is the largest know cave system (over 80 km), the *Codula Ilune* in Sardinia (over 70 km), the *Valle del Nosè* system in Lombardy (over 61 km); the *Monte Corchia* complex (about 57 km) in Tuscany; the *Piaggia Bella* system (over 43 km) in Piedmont and the *Piani Eterni* complex (about 37 km) in Veneto. Less extended, but yet really interesting, are the gypsum caves in Sicily and Emilia Romagna, and the cave system developed in the *Montello* conglomerate in Veneto.

Mount Etna in Sicily, the largest active volcano in Europe, offers marvellous examples of basalt caves (lava tubes and eruptive fracture).

Italy offers an extremely complex speleological scenario, continuously updated thanks to the unceasing activity of exploration and research throughout its territory.

## NUMBER OF REGISTERED CAVES: 44362

| Longest caves | |
|---|---|
| **Name** | **Length (m)** |
| Complesso del Monte Canin (Chiusaforte - Friuli Venezia Giulia) | > 80,000 |
| Complesso carsico della Codula Ilune (Urzulei-Baunei-Dorgali - Sardegna) | > 70,000 |
| Complesso Valle del Nosè (Sormano/Zelbio- Lombardia) | > 61,000 |
| Complesso del Monte Corchia (Stazzema - Toscana) | > 57,000 |
| Complesso di Piaggia Bella (Briga Alta - Piemonte) | 43,000 |

Grotta del Corchia "ramo dei lucchesi" (Tuscania)
Ph. Silvia Arrica

| Deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| Abisso Paolo Roversi (Minucciano - Toscana) | - 1,300+50 |
| Abisso Olivifer (Massa – Toscana) | - 1,215 |
| Complesso del Grignone Alfredo Bini (Esino/Mandello Lario - Lombardia) | - 1,190 |
| Complesso del Monte Corchia (Stazzema - Toscana) | - 1,187 |
| Abisso Perestroika (Minucciano - Toscana) | - 1,160 |

Su Palu (Sardinia)
Ph. Victor Ferrer

Grotta dei Tre livelli, vulcanic cave (Etna, Sicily)
Ph. Francesco Maurano

Grotta Nettuno (Sardinia)
Ph. Victor Ferrer

## MARINE CAVES: ~5000

| Most important marine caves | |
|---|---|
| **Name** | **Length (m)** |
| Grotta del Bue Marino Dorgali | 17,400 |
| Grotta del Bel Torrente | 7,665 |
| Grotta dell'Utopia Baunei | 3,716 |
| Grotta di Nettuno Alghero | 2,770 |
| Grotta Verde Alghero | 880 |
| Grotta di Punta degli Stretti Monte Argentario | 1,335 |
| Grotta del Fico Baunei | 1,134 |

## ARTIFICIAL CAVES: ~5155

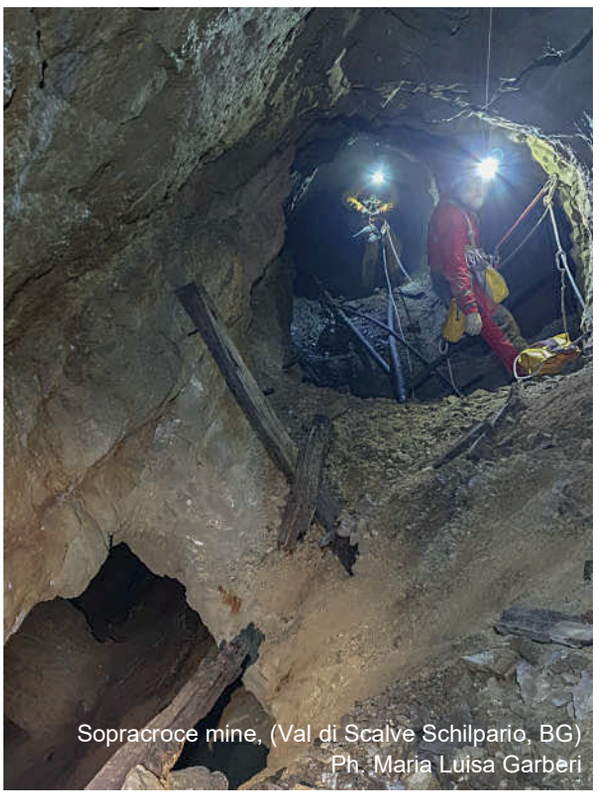
**Brief state of the art in artificial speleology**

The Italian heritage of artificial cavities (CA) is a vast set of diversified caves, both in the different main uses for which they were designed, and in the technical construction features that the different human cultures have devised over the centuries. The time frame concerned, in fact, is extensive and rich in testimonies ranging from the prehistoric period to

the whole contemporary age; in this wide temporal spectrum, the various cultural realities have devised formidable solutions, both for exploitation of subsoil and water resources, and for the creation of underground spaces that respond to the needs of daily life over the centuries. In 1981, within the Italian Speleological Society (SSI), the "National Commission of Artificial Cavities (CNCA) was established which is committed to promoting the exploration and study of the underground caves, not only among the speleologists but also involving and strictly linked to the national and international scientific and academic world in the network of collaborations.

In 1989 the Commission establishes the "Catasto Nazionale delle Cavità Artificiali" (National Cadaster of Artificial Cavities), the data base with which the typological catalogue of CA is updated, sharing it also in the context of the International Union of Speleology (UIS); to this end, it conceived the classification of artificial cavities by dividing them both on the basis of the "intended use", identifying seven main types divided in turn into sub-types, and classifying their construction characteristics.

The CNCA analyzes the data acquired by speleologists during research conducted in Italy and abroad, produces the national and international reference symbology and contributes to the updating of the UIS multilingual dictionary for artificial cavities.



Sopracroce mine, (Val di Scalve Schilpario, BG)
Ph. Maria Luisa Garberi

It develops typological synthesis projects and thematic censuses such as, for example, "The National Map of the ancient aqueducts" and the "Census of artificial emissaries of endorheic basins". Since 1999 the Commission has edited the publication of the journal "Opera Ipogea -Journal of Speleology in Artificial Cavities", edited by SSI, a unique journal for testimony and memory of the ancient underground works in Italy and in the world. The anthropic cavities, in addition to preserving archaeological finds, may themselves be architectural assets of considerable cultural and scientific value.

To face up with the diversified reality of Italian subsoil, the cavities were classified according to their original intended use, identifying seven important types: **military works**, mainly concentrated at the NE boundary areas of Italy; **hydraulic works**, testifying the capability of ancient civilizations in tapping, transporting, collecting and distributing the water resources; **religious works** are more frequent in southern Italy and are often connected to civil or monastic rock settlements; **civil settlement works**, distributed in all Italian regions, including the islands; **works of communication or transit**, underground infrastructures widespread since ancient times; and, finally, **mining works**, which in recent years have been the subject of important speleological investigation campaigns thanks to innovative techniques and the use of specific equipment. A final typology groups the so-called **other cavities** that do not fall into any of the above-mentioned groups.

Aqueduct Carolino (Maddaloni, CE)
Ph. Francesco Maurano

## NATIONAL CAVING ORGANIZATIONS:

Società Speleologica Italiana www.speleo.it
Club Alpino Italiano CAI www.cai.it/

## NUMBER OF SPELEOLOGISTS: ~5500

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATION: 293

## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLICATION:

*"Speleologia"* http://www.speleologiassi.it/ ;
*"Opera Ipogea"* http://www.operaipogea.it/

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST:

Società Speleologica Italiana www.speleo.it
SPELEOTECA www.speleoteca.it
Club Alpino Italiano www.cai.it
CAI / Bossea http://caicsc.it/chi-siamo/gruppi-e-strutture/il-laboratorio-carsologico-di-bossea

Grotta Guernica (Parco delle Dolomiti Bellunesi)
Ph. Sandro Sedran

## BIOSPELEOLOGY

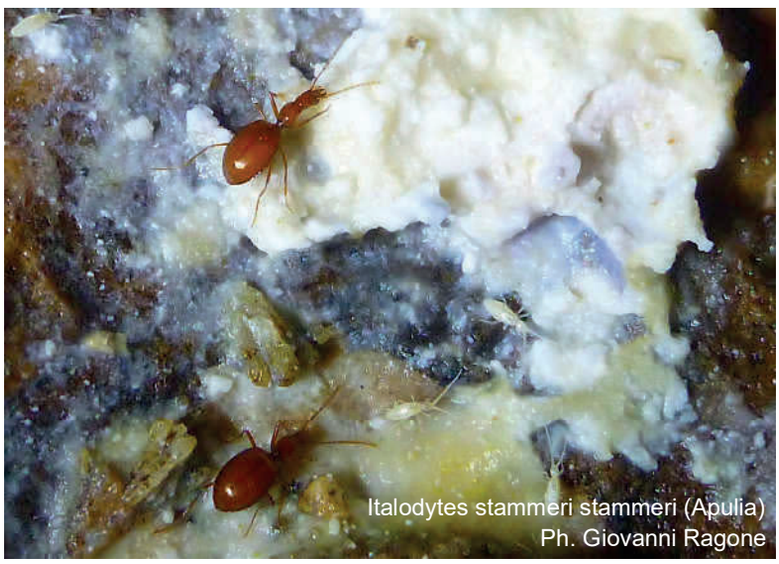
**FAUNA CATALOGUE**. The catalogue contains more than 5658 cavities (natural and artificial ones); it takes into account 3674 species, 556 subspecies and several other taxa. At least 785 species are regarded as eucavernicolous (i.e. troglobites + eutroglophiles).

The zoological orders with the highest numbers of eucavernicolous species are Coleoptera (382), Pseudoscorpiones (92), Araneae (72), Diplopoda (65), Isopoda (55).

On the other hand, the higher frequency of endemic species is among Coleoptera (317), Diplopoda (105), Isopoda (104), Pseudoscorpiones (86), Araneae (60). As karst is widespread in all Italian regions, we would have expected to obtain, using the acquired information, a list of caves with more or less homogeneous faunistic quotations. The encountered het-

erogeneity in faunistic knowledge is due to the fact that biospeleological research started in different times in different regions.

In the second half of the 19th century faunistic research began to be carried out in particularly important caves, for quantity and diversity of species, in territories not very far from zoological research centers, such as in Veneto and Liguria.


Italodytes stammeri stammeri (Apulia)
Ph. Giovanni Ragone

In the first six decades of the 20th century many publications dedicated to the speleofauna were produced for caves in other Italian regions (in order of importance: Lombardy, Apulia, Venetia Julia, Piedmont, Tuscany and Friuli). However, a real leap of quality occurred since the 70s with the intensification, at national level, of speleological explorations, the discovery of many new caves, and the description of many new speleofaunistic entities.

In this context it is particularly interesting to highlight the importance of Sardinia, a region rich in caves where many endemic species are living. Many of these species have significant affinities with others living in caves of eastern Spain, the Balearic Islands, the Pyrenees, Catalonia and Provence. This can easily be explained by the geological history of this Island. Sardinia and Corsica, during the Oligocene, shifted from the Provençal area towards Italy up to the actual position in an anticlockwise roto-translation.

## LEGAL STATUS OF CAVES AND PROTECTION RULES

Both natural and artificial caves in Italy are not protected at the origin but only by special laws on extractive activities, mineral waters, archaelogy and fine arts, or by Parks, Reserves and regional laws. Specifically, the underground mines stay under the dictates of the D.P.R. no. 128 of 09/04/1959 (Police regulations of mines and quarries, updated with Legislative Decree no. 624/96) while cavities of historical-archaeological interest or of particular geological singularity are protected by the Code of Cultural Heritage and Landscape (Legislative Decree 22.01.2004 no. 42). Finally, almost all Regions have provided rules on the protection of speleological heritage and geodiversity.

The framework law on the environment (Legislative Decree 152/2006) does not explicitly mention caves and karst systems, but it leads back to it.

The Habitats Directive (92/43 / CEE) also deals with caves: caves that are not exploited for tourism are habitats of community interest, included in the list of Annex I of the Directive with the code 8310, while submerged or semi-submerged sea caves are present with code 8330. Furthermore, limestone pavements are listed (8240) which constitute "priority"

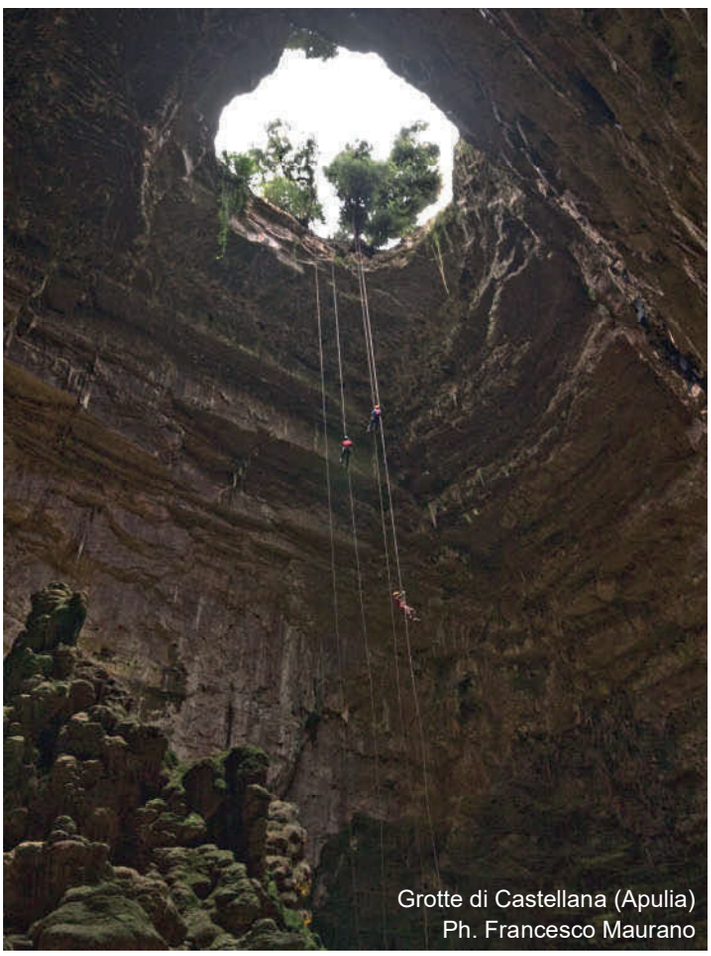

Grava del Parchitiello I (M. Alburni, Campania )
Ph. Francesco Maurano

habitat for the European Union. On the basis of the Habitat Directive, therefore, caves are protected within the limits of the network Natura 2000, but the State undertakes to guarantee a certain protection on the whole national territory.

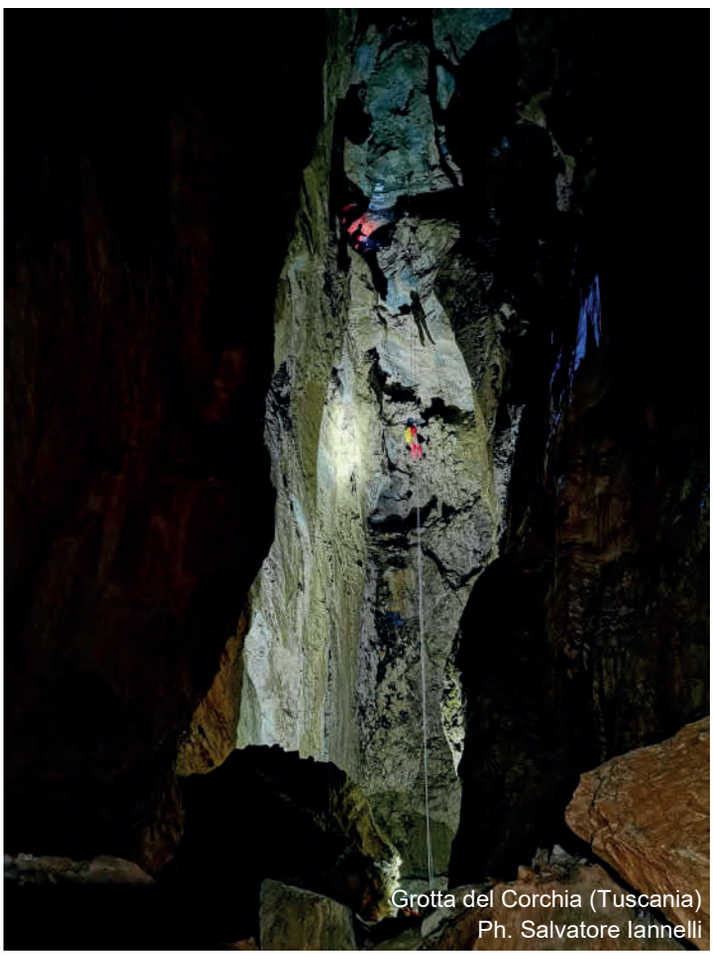
**Access to the subsoil follows the same principles as the private ownership of the surface**: the entrance and the underlying cavity belong to the owner of the land in which they open, who has the right to prevent access by closing or through other protections. Any free entry implicitly allows exploration of the cave.

Water and Caves: Even before the Urban Code and Legislative Decree 152/2006, groundwater is protected pursuant to Royal Decree no. 1775/1933, a legislation that is still in force and constitutionally valid.

Groundwater is subject to safeguard pursuant to Legislative Decree 152/2006, which provides specific quality objectives for them, in implementation of Directive 2000/60 / EC. The regulation presents however, a deficiency related to groundwaters. Decree 152/06, in fact, deals with underground waters constituting aquifers. Surface waters are subject to other protective measures, but nothing is explicitly referred to groundwaters. In Italy a mosaic of national and European laws and regulations contributes to the protection of the caves; often the creation of parks and reserves constitute the strongest form of protection for caves and karst areas.



Grotte di Castellana (Apulia)
Ph. Francesco Maurano



Grotta del Corchia (Tuscania)
Ph. Salvatore Iannelli

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# KOSOVO

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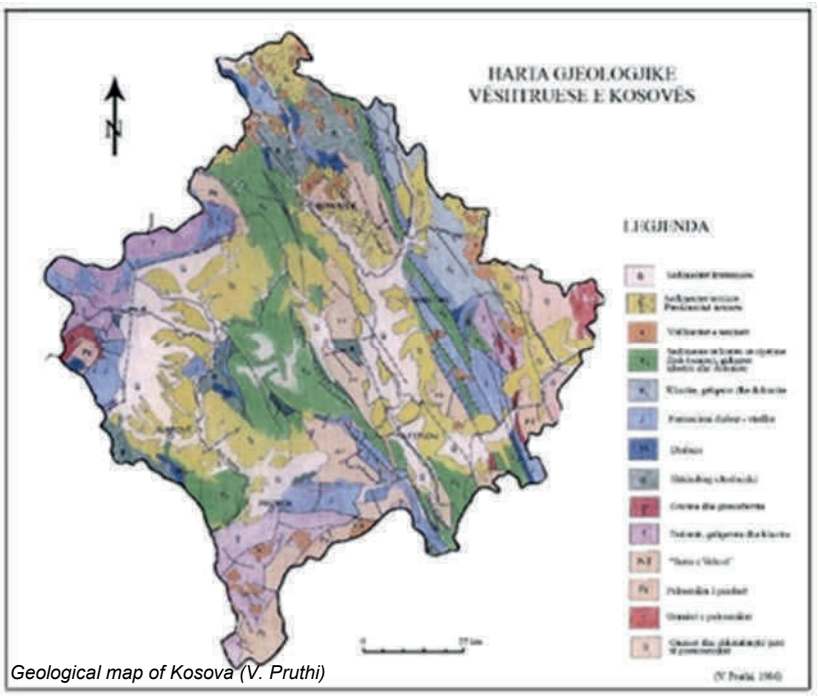
Cave in Kusar
Ph. Fadil Bajraktari

## GENERAL INFO

Kosovo is located in the central part of the Balkan Peninsula, with the surface of 10,908 km$^2$, and with over 2 million inhabitants. It has a favourable geographical position and is located at important transversal and longitudinal roads of the Balkan Peninsula. The geological structure, relief, climatic conditions, hydrography and biological diversity are special features of the territory of Kosovo.

From geological perspective, Kosovo is located in a very specific area. It is characterized by a distinguished diversity of geological formations. It starts from the old crystalline rocks of Paleozoic up to quaternary rocks, including various types of sedimentary and magmatic rocks and metamorphic rocks that are less prevalent



*Geological map of Kosova (V. Pruthi)*

## TECTONIC-STRUCTURAL CHARACTERISTICS

Kosovo territory belongs in spatial aspect to two great geo-tectonic units and that in the greatest part to Dinaro: Albanid Orogen and Dardane crystalline core. These geo-tectonic units are distinguished in Kosovo: Dardane crystalline core, ophiolite zone of Vardar, Microtile of Korab-Sharr -Pellagonia, ophiolite zone Mirditë-Dukagjin and West peripheral unit.

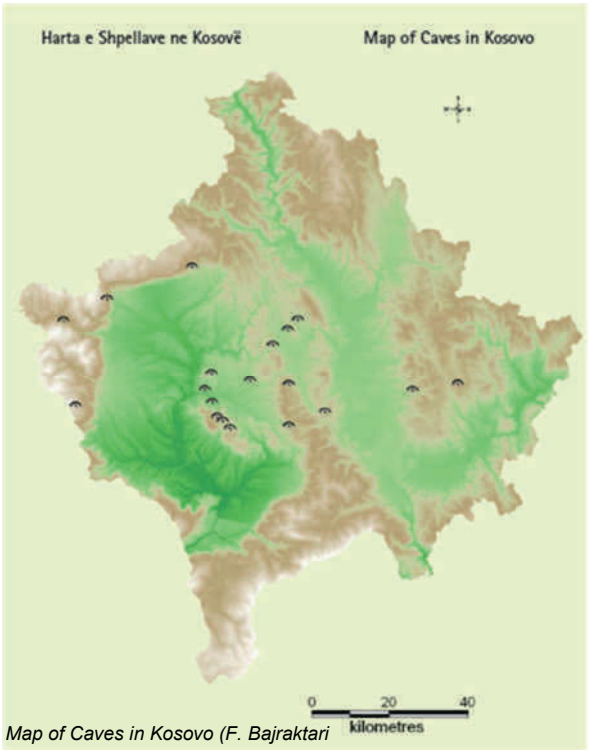
## KARTS AREEAS

Karst terrains in Kosovo are built from karstified limestone of Triassic and Cretaceus periods and of Paleozoic marble. These terrains include an area of 1,423 km$^2$ or 13.1% of Kosovo's territory. There are created numerous surface and underground forms of relief, where caves are the most important. Caves in Kosovo are quite common, but very few of them are researched and opened for visitors.

In Kosovo there are a considerable number of caves that have been inhabited since prehistoric times, but speleological research in Kosova is late, they date from the 60s of the last century[1]

Caves in Kosovo are quite widespread, but few of them are studied and open to visitors. To date, over 200 caves and abysses have been registered in Kosovo, but it is thought that the number is much higher. The largest number of caves and abysses identified so far, are found mainly in the massif of Bjeshkët e Nemuna, Mali Akovan (Zatriq), Mali Mokna, Pashtrik, Malet e Sharrit, Malet e Drenicës, Koretnik, as well as downstream the flow of the Mirusha River.

Among the most important caves in Kosovo that are known to the general public is the Cave in Gadim, which due to the aragonite crystals of various shapes and sizes is considered as a rare cave in the world. Caves in Kosovo are distinguished with numerous stalactites and stalagmites, characterised with columns and lunette decorations. These ornaments in different shapes and sizes with astonishing colors are present in most of Kosovo caves. The forms



*Map of Caves in Kosovo (F. Bajraktari*

[1]Lack of data for the exploration of caves and karst terrains before the 60s of the last century. But in the future, young researchers in this field will be able to obtain reliable data on the karst and cave research in Kosovo even before the 60s of the 20th century that will enrich the inventory on caves in Kosovo.

of surface and underground relief are very well preserved and represent the values of a karst museum of nature.

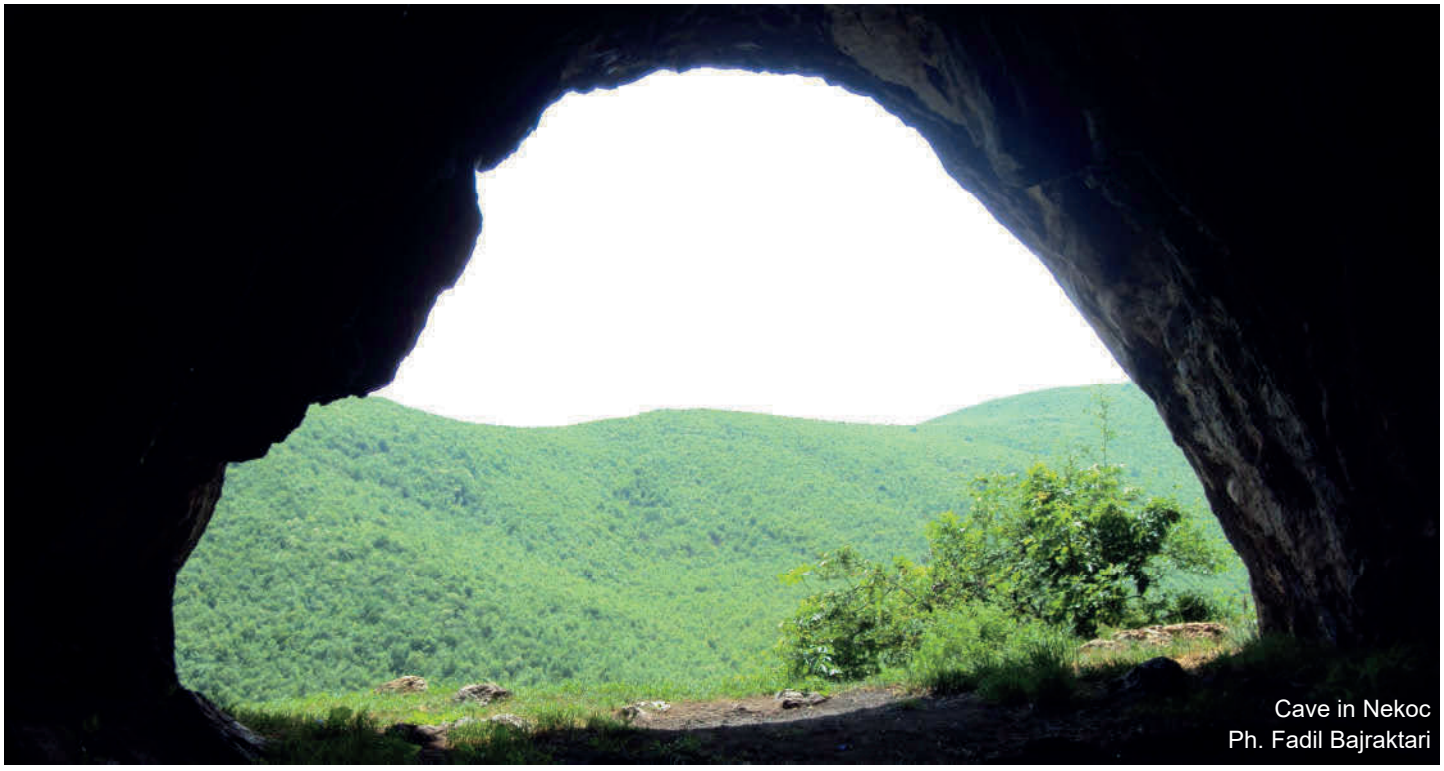
## NUMBER OF REGISTERED CAVES: 214

**Longest caves**

| Name | Length (m) |
|---|---|
| Grand Canyon Cave | 13,954 |
| Cave in Radavc | 2,100 |
| Cave in Gadime | 1,250 |
| Cave in Panorc | 955 |
| Cave in Dush | 651 |
| The Robber's Grand Cave (Shpella e Madhe e Kusarit) | 102 |
| Grand Cave of Gollostena (Shpella e Madhe e Gollostenës) | 133 |
| Cave of Devetak (bats) Shpella e Devetakut (Iakuriqëve) | 145 |
| The Inhabited Cave (Shpella e Banuar) (Gërgavica) | 93 |
| Cave in Kishnarekë | 95 |
| "Black Scissors"Cave (Shpella "Gërshërët e Zeza") | 113 |

**Deepest caves**

| Name | Depth (m) |
|---|---|
| Cave (Abyss) of Zgatar (Shpella /Humnera e Zgatarit) | - 102 |
| Cave in Radavc | - 101 |
| Azem Galica's Cave (Shpella e Azem Galicës) | - 71 |
| Bad Cave Abyss, (Shpella /Humnera e Keqe) | - 68 |
| The White Queen's Cave (Shpella e Mbretreshës së Bardhë) | - 48 |
| Endless Cave (Shpella pa fund) | - 44 |
| The Pidgeons' Cave (Shpella e Pëllumbave) | - 26 |



Cave in Nekoc
Ph. Fadil Bajraktari

## NATIONAL CAVING ORGANIZATION


Cave in Gadime
Ph. Fadil Bajraktari

There are few non-governmental organizations operating in Kosovo that have environmental protection in their core program. Within the Mountaineering Federation of Kosovo operate a considerable number of Mountaineering associations, which in their program treat the field of Speleology little or not at all. With the assistance of Italian Speleologists in 2002 in Kosovo, there was established the Speleological Association "Aragonit" based in Peja. This association, in cooperation with speleologists (Czech, Polish, English, etc.) from different European countries has conducted several speleological research expeditions in the Bjeshkët e Nemuna Mountains. These expeditions have mainly been focused on the research and mapping of caves such as: Gryka e Madhe Cave and Radavc Cave. Their presentations have also been shown in various conferences and publications.

Another active organization which in its program has the inventory and protection of geoheritage is the association ProGEO-Kosova, established in 2010. Its representatives are members with equal rights of the European Association for the Protection of the Geological Heritage.

In 2011 in Kosovo there was established the Kosovo Speleologists' Federation, which, to date, does not have any important activity in the field of speleology.

## NUMBER OF SPELEOLOGISTS

The number of speleologists in Kosovo is very small and does not exceed 10 people.

## PUBLICATIONS


The most complete publication to date on caves in Kosovo is the publication of the monograph "Kosovo Caves" ("Shpellat e Kosovës") (2010) published by the Association ProGEO-Kosova (the European Association for the Conservation of the Geological Heritage) by authors: *Fadil Bajraktari*, *Sami Behrami* and *Fatos Katallozi*. In this publication a total of 19 caves are described, a morphological description is made, the caves are presented in photos and a map of Kosovo caves is published. There are also some publications (reports) from speleological expeditions to certain caves and areas but they are few.

## BIOSPELEOLOGY

In the field of biospeleology in the Kosovo Caves there is no research or data on the flora and fauna of caves in Kosovo (except for some data on the species of bats that have been published in the Red Book of Fauna 2019).

In the underground karst environments of the caves in Kosovo (Inhabited Cave (Shpella e Banuar) - Zatriq, Radavc Cave, Nekoc Cave, Kishnareka Cave, The Grand Gorge Cave (Shpella Gryka e Madhe), The Robber's Cave (Shpella e Kusarit), The Candles Cave (Shpella e Qirave), Peshterri Cave - Zatriq, etc.). live 22 species of bats. Of these, 1 species of bats (*Rhinolophus blasii*) which is present in the Radavc Cave and the Inhabited Cave (Zatriq), is in the category endangered (VU), 6 species of bats were found in the category almost endangered (NT), 6 species in the category minor concern (LC) and 9 species of bats in the category insufficient data (DD) [2].



Bats (*Rhinolophus ferrumequinum)* in the Robber's Cave (Shpella e Kusarit) (Ph. Fadil Bajraktari)

[2] Ibrahimi H., (ed.) Red Book of Fauna of the Republic of Kosovo, (2019), Ministry of Environment and Spatial Planning, Kosovo Institute for Nature Protection, Pristina.
Endangered (VU), Almost Endangered (NT), Minor/Low Concern (LC), Insufficient/Deficient Data DD, Explanation of these terms according to the IUCN Manual "Categories and Criteria of the Red Lsit of IUCN (Version 3.1)", IUCN 2012.

## LEGAL STATUS OF CAVES AND PROTECTION RULES

The legal protection of caves in Kosovo is regulated by the law on nature protection (No. 03/L-233)[3]. Caves by law are categorized in the category Natural Monument. According to the IUCN (International Union for Conservation of Nature) natural monuments belong to the third (III) category of protected areas. The articles of the law on nature protection, which regulate the protection of speleological objects are Article 52, 53 and article 54. According to the law, speleological objects are property of the Republic of Kosovo.

This law also regulates the activities that are permitted to take place in speleological objects. For all activities in the speleological objects, permission must be obtained from the Ministry of Environment and Spatial Planning, particularly for: use and regulation of the speleological object and its parts; opening and/or closing the entrance/exit to the speleological object, as well as for the construction, renewal or rehabilitation of any underground object; conducting scientific and professional research; immersion in a speleological object; shooting films in speleological objects; works and activities which affect the basic features, conditions and natural flora and fauna of the speleological object or on its surface; organized visits and photographing in speleological objects are conducted with the permission of the administration of the speleological object.

Due to cultural and historical importance, some caves are also found in the list of cultural heritage (protected by the Ministry of Culture), such as Radac Cave (archeological site) The Monks' Cave (Shpella e Murgjëve) in Rugova Gorge (Gryka e Rugovës) (Medieval period), Bresallc Cave and Resule Cave, etc.

The number of protected caves in Kosovo is 20 (2020) which includes an area of 459.79 ha., or 0.4% of the surface of protected areas. But a large number of caves are located within protected areas such as: National Park " Bjeshkët e Nemuna" (Gryka e Madhe (The Grand Gorge) Cave, Gërshërët e Zeza (Black Scissors) Cave, etc.). While in the National Park "Sharri" there are about 30 speleological objects, with a total of 994.5 m, corridors and underground galleries or about 5,312 $m^2$. The most important caves and abysses in NP "Sharri" are: (The Navy Abyss) Humnera e Marinës (195 m.), The Zgatar Abyss (103.5 m), etc.

In recent years in Kosovo there have been identified, explored and taken under protection a considerable number of caves, but still many caves with hydrological, biological, geomorphological, cultural and tourist values have remained without legal protection.

[3] The Official Gazette of the Republic of Kosovo/Pristina, year V/No. 85/09 November 2010.

Cave in Panorc
Ph. Fadil Bajraktari

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# LEBANON

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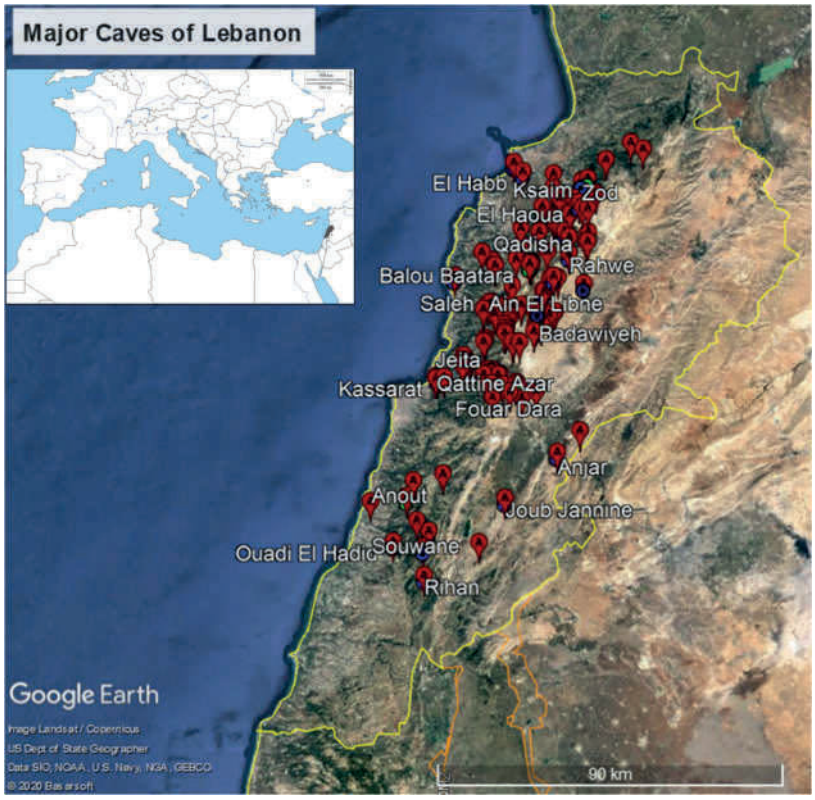
Dakhoun Sinkhole
Ph. Johnny Tawk

## GENERAL INFO

Lebanon covers 10,452 km$^2$ of surface area and stretches along the central eastern coast of the Mediterranean Sea. It consists of two mountain chains (Lebanon and Anti-Lebanon) separated by a high inland plain (Bekaa). The western chain (Mount-Lebanon) borders the Mediterranean Sea, displaying relatively gentle slopes on its western flanks and steeper ones on its eastern flanks. The highest point in Lebanon is located in the northern part of this mountain chain; Qornet es Saouda, 3,083 m above sea level (asl). Both mountain chains are predominantly made up of Mesozoic carbonate rocks.




Some cave exploration activities have been reported since the 19th century – other similar activities in pre-historic and historic time are excluded here; yet the organized speleology started with the birth of the Spéléo-Club du Liban (SCL) in 1951, one of the first organized caving associations in the Middle-East (https://speleoliban.org/).

More than 1000 caves have been explored and reported since the 1950s. In 1954, the Jeita cave was explored and mapped by the SCL, leading to the first and one of the most visited show caves in the Middle East. In 1962, the deepest sinkhole in Lebanon up to this date (Foura Dara) was discovered and explored (see below).

## KARST AREAS

About 70% of the Lebanese territories are covered by karst. Rain and snow fall in abundance on the Lebanese mountain chains, especially on Mount-Lebanon. The precipitation rate varies between 700 and 1200 mm/year with increasing elevations (i.e. higher altitudes) across Mount-Lebanon, and about 80% of the yearly precipitation falls from November through February.

The karstic features in Lebanon can be grouped into three areas based on landscape and climatic conditions: a highland area (> 1,500 m asl), where the deepest vertical caves in Jurassic strata have been found (e.g. Fouar Dara, - 620 m), an intermediate area (500 to 1,500 asl) where Cretaceous strata prevails including maze caves (e.g. Afqa, 1,200 asl), and a coastal area (< 500 m), where the longest karstic systems are located in the Jurassic strata (e.g. Jeita, ~ 10 km, Kassarat, 4.6 km) draining out the aquifers, and where coastal caves in Cretaceous and Cenozoic strata prevail.

## NUMBER OF REGISTERED CAVES: ~500

**Most important caves**

| Name | Length (m) | Depth (m) |
|---|---|---|
| Jeita | 10,050 | - 140 |
| Qattine Azar | 8,700 | - 535 |
| Roueiss | 5,411 | - 80 |
| Afqa | 5,260 | |
| Kassarat | 4,648 | |
| Fouar Dara | 4,000 | - 622 |

## MARINE CAVES: 7

**Most important marine caves**

| Name | Length (m) |
|---|---|
| Grotte aux Phoques | 35 m |
| Grotte aux Pigeons | |
| Maameltein | 15 m |

## ARTIFICIAL CAVES: 5

Old mines (in sandstones and carbonate rocks), tunnels for draining springs and for shelter have been explored in Lebanon. Some mines were used to extract iron ores (e.g. Marjaba mines), others to extract coal/lignite in sandstones and even seeking oil (e.g. Sohmor, Hasbaya; see below).

## NATIONAL CAVING ORGANIZATION

There is no national caving organization (federation) in Lebanon to date. Caving activities are organized by separate groups (see below).

**Most important artificial caves**

| Name | Length (m) | Depth (m) |
|---|---|---|
| Marjaba Mines II | 2,272 | - 35 |
| Marjaba Mines | 570 | |
| Ouadi El Hadid | 460 | - 10 |
| Sohmor Mines | | - 65 |
| Hasbaya Mines | | - 45 |

Moutrane Cave
Ph. Johny Tawk

## NUMBER OF SPELEOLOGISTS: ~70

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS:

- Spéléo Club du Liban (SCL)
- Spéléo Club Wadi Al-Arayech (SCWA)
- Groupe D'études et de Recherches Souterraines du Liban (GERSL)
- Association Libanaise d'études spéléologiques (ALES)

## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLISHING:

- Al Ouat'Ouate (Spéléo Club du Liban)
- Liban Souterrain (GERSL)
- SpéléOrient (ALES)

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST

Members of the speleological organizations (mentioned above) have traditionally been involved (and initiated) scientific research for karst and caves in Lebanon. In most cases, they were also associated to the local universities – e.g. American University of Beirut (AUB), Université Saint-Joseph (USJ), Université Libanaise (UL), Université Saint-Esprit Kaslik (USEK) – and the Lebanese National Council for Scientific Research (L-NCSR).

## SPELOBIOLOGY

Between 2007 and 2009, several census campaigns have been achieved in Lebanon. For more info check https://speleoliban.org/index.php?f=The_bats_of_Lebanon

## LEGAL STATUS OF CAVES AND PROTECTION RULES

While the cave itself cannot be privately owned according to the Lebanese regulations, the entrance is part of the land property, except if a protection zone is decreed around it by the Government (Ministry of Environment and/or Ministry of Energy and Water). This is usually done for karst springs and for special karst features (e.g. Balou' Baatara (three-bridge) sinkhole).

The legal status and protection rules for groundwater do exist and they include the major caves and karst terrains.

Baatara Sinkhole
Ph. Johny Tawk

Lebanon has fourteen natural reserves, most of which include karstland and karstic features. The country has also five UNESCO world heritage sites, including Ouadi Qadisha which is a historical valley carved mostly in karstified Jurassic carbonate rocks.

Balou' Baatara (three-bridge) sinkhole
Ph. Fadi Nader

# LIBYA

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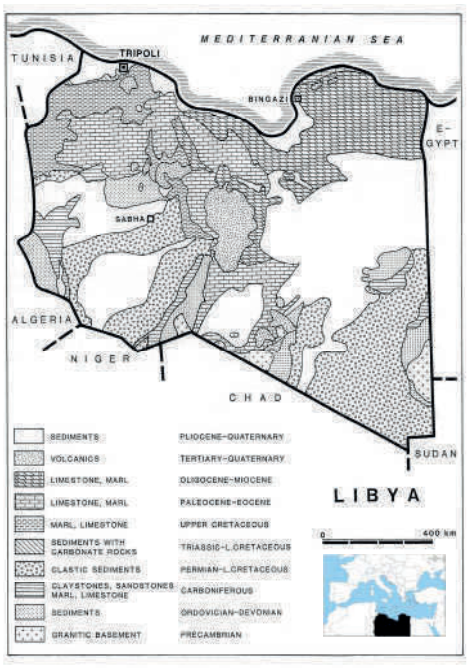
Brag Notta Karst area
Ph. Rosario Ruggieri

## GENERAL INFO

Libya is a large country with a relatively small population, and the population is concentrated very narrowly along the coast. Population density is about 50 inhabitants per square kilometer in the two northern regions of Tripolitania and Cyrenaica, but falls to less than 1 inhabitant per square kilometer elsewhere. Ninety percent of the people live in less than 10% of the area, primarily along the coast.

Libya is the fourth largest country in Africa and extends over 1,759,540 km$^2$, making it the 16th largest nation in the world by size. Libya is bound to the north by the Mediterranean Sea, the west by Tunisia and Algeria, the southwest by Niger, the south by Chad, the southeast by Sudan, and the east by Egypt. Libya lies between latitudes 19° and 34°N, and longitudes 9° and 26°E.

At 1,770 kilometers, Libya's coastline is the longest of any African country bordering the Mediterranean. The portion of the Mediterranean Sea north of Libya is often called the Libyan Sea. The climate is mostly extremely dry and desert like in nature. However, the northern regions enjoy a milder Mediterranean climate.



Geological map of Libya (according to Bosse et al. 1996)

## HISTORICAL ASPECTS

The first studies and the first real speleological explorations were conducted by Mühlhofer in the years 1911-1912, by Leonardo Ricci (1922) and Marchetti (1938) in Cyrenaica, the latter mentioning the presence of numerous vertically drained shafts throughout the Gebel, including the shaft of en-Nur and the shaft of Bu Labia (Bu Làhia) detected by Mühlhofer (1928), caves with internal circulation (Lete cave, Sotira and Bu Carma caves), of active springs, including Ain Sciahàt, Ain Messa and Berghes.


Hawa Egere
Ph. Rosario Ruggieri

In the following decades, especially in the second half of the last century, the real exploration of the Cyrenaic caves begins, both for purely speleological purposes, by the Roman Speleological Circle in the years 1959-1960 between Bengasi and Al Beyda (Marzolla, 1969), as well as hydrogeological and karst surveys, carried out on behalf of the Libyan government by Comex and Societè des Eaux de Marseille in 1977 (with Bertrand Léger's speleosubwater explorations for Hydrokarst with dives as early as 1975 of the Ayn Zayana system), and from Attila Kòsa's Hungarian team between 1979-1981. Further explorations and studies on karst were carried out in the 1980s by Fileccia (1983) and in the early years of the following century by Ashahomi (2008) and by Ruggieri of CIRS Ragusa (2008, 2013), the latter in collaboration with the University of Benghazi as part of the Cyrenaica Karst Project .

## GEOLOGY OF LIBYA

Base rock of Libya is covered by sedimentary layers of varying thickness and geological age. Even if we construct a timeline for Libya's geological evolution, we discover that its development dates back to the pre-Cambrian era to Ceno-

zoic era. on the pre-Cambrian, the Libyan lands represented a rocky mass, which is part of the old continent, and the ancient sea covered most of its lands. At this time, the Archaean rocks, represented in the Al-Uwainat region, were of great importance in benefiting from them because they contain precious metals such as silver, gold, copper, tin and zinc.

On the Paleozoic, there were tides of the sea and covered large area of Libya and then confined in a later period and thus its waters increased in breadth and depth, which led to formation of marine calcareous sediments and sand over the rocks of the Archean base. As the southern parts of Libya were exposed during the tectonic movements, they led to severe torsions that led to the formation of southern mountain chains, the impact of which was Tibesti, Al -Aweinat, and Acacus, accompanied by volcanic activity whose overflows covered large area. On the Mesozoic, the central parts of Libya were exposed to sea level transgression and then retreated at its end, which led to the activation of erosion's factors forming continental sediments and the formation of limestone and chalk and various deposits of sand, clay, and shale, and containing fossils such as shells and reptiles. They are marine sediments that are a storehouse of groundwater and are fed from sources that reach more than 3,000 km. The water appears in the form of wells and springs in desert oases. It also contains oil fields, especially the Cretaceous formations.

On the Cenozoic, the central and northern parts of Libya were subjected to a subsidence that led to the transgression of sea level and its retreat after a subsequent lifting movement, which led to the exposure of the limestone layers. Several torsional movements and volcanic eruptions also occurred. The torsional movement formed the mountains of northern Libya (Al Jabal AlaKhdar). The volcanic formations also resulted in the emergence of the Black Haruj Mountains in the middle of the Libyan desert. The formations of this time are limestone in large areas, especially the meeting of the Fezzan Cyrenaica, Tripoli, the rocks of the Mediterranean coast and the sandy gravel deposits, which contain traces of terrestrial and marine animals.

On the recent, the movement of torsion, volcanic eruptions and the spread of eruptions continued, and Libya, especially the southern regions, was exposed to a humid climate and heavy rains, and water erosion factors were activated, which led to the formation of sandy sediments that filled the valleys, as well as dunes of cohesive and incoherent sand sediments and the formation of a limestone raft around the springs in the oases.

Shigeia Cave
Ph. Gianni Savasta

Ahrishieh Cave
Ph. Belkasem Alkaryani

Hawa Bunaidoah
Ph. Davide Messina Panfalone

## KARST AREAS

Although the Libyan desert covers 90% of the country the remaining portion is covered by carbonate rocks which has high potential to have karstic features.

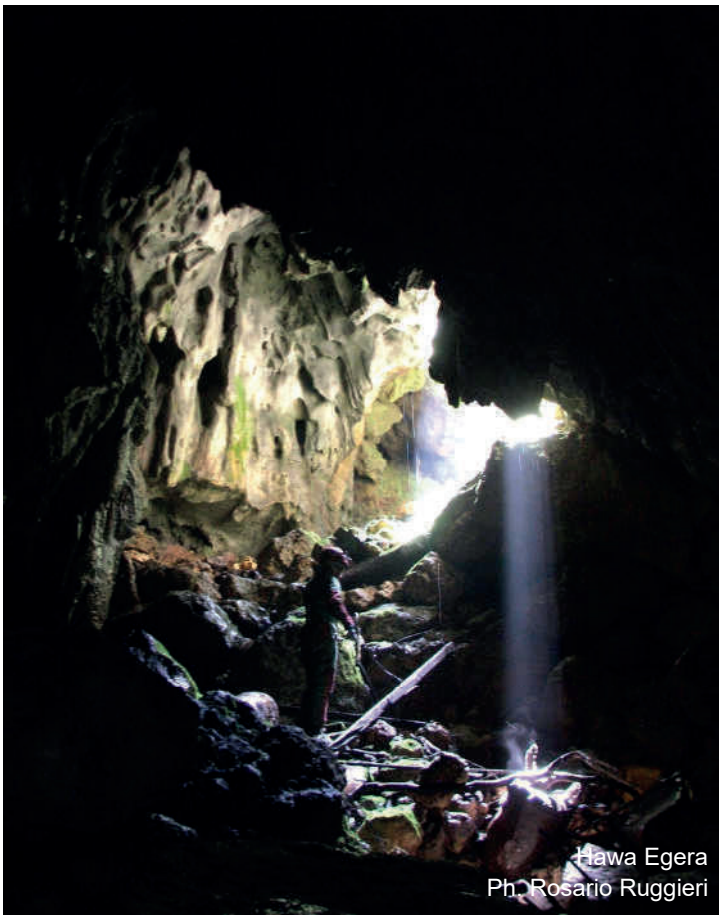
In the west part of the country, the Bir Al Ghanam gypsum formation there is with 400 meter thickness southwest of Tripoli. the longest gypsum cave in Africa is Umm al Masabih, with 3,593 km surveyed. Also, present are three significant systems in the Abu an Niran area, 0.5 to 1.0 km long. Each of these consists of three physically separate segments. The Ain Wadi Fasat system also has three separate segments, with a total of at least 600 m of passage; further exploration appears feasible. Other gypsum outcrops in Tripolitania also appear karstified.

The Al Jabal Alakhdar is considered as Karstic region, situated in the northern part of Libya and is characterized by three remarkable escarpment linear feature. These three escarpments are resulting from major three uplifting events. The Al Jabal Alakhdar rock exposes a 2,000 m succession of late Cretaceous-Miocene carbonate rocks. This carbonate rock tends to Karstic aquifers by dissolution processes that create a significant Karst groundwater. The lowest escarpment runs parallel to shoreline to the Mediterranean Sea. Its height is ranges between 250 and 300 m. Its width decreases from about 20 km in the west to about 1km in the east at Ras Al Hilal area. The second escarpment elevations range usually from 450 to 600 m. Moreover, the last escarpment is not rugged like the first two edges and the maximum elevation is 880 m in 'Sidi Mohamed Alhamri area.

Distribution of caves in Libya

**Most important caves**

| Name | Length (m) |
|---|---|
| Unmm al Masabit | 3,593 |
| El Mirisi | 2,117 |
| | **Depth (m)** |
| Hawa Balkhtak | - 140 |
| Bukarma-El-Habibi | - 92 |



Hawa Egera
Ph. Rosario Ruggieri

## NUMBER OF REGISTERED CAVES: ~83

Not easy to account for every cave in Libya due to vast area of the country, and many caves located in remote areas, on private land and on military bases. Anyway, the following figure and table is current work start from a few months ago of 'Libyan National Speleology Organization' which based on previous study, and maps made by various governmental and nongovernmental firms. This is we believe is not even 30% of actual Libyan caves. As figure demonstrate most caves or known caves in Libya are located in eastern part of country due to the geological and climes conditions which are the favorable for karstic process developing.

## SINKHOLES

Cyrenaica region is rich with sinkholes varyng in size and depth at Miocene and Eocene deposits. It can be single sinkhole or accompanying with other sinkholes.

The sinkhole field in the area between Soluq city and Msuss city consists of 57 sinkholes 13 of which are classified as doline-like shallow depressions (i.e. diameter ranges from 125 to 350 m and depth from 5 to 25 m) and the other 44 are collapsed dolines (i.e. diameter ranges from 75 to 250 m and depth from 25 to 60 m) are placed on Miocene rocks. Th

Kawifyah formation another Miocene sinkhole field located in eastern part of Benghazi city with 59 in total of varied type of sinkholes includes collapsing, dissolutions, and lake dolines. Dye tracing operations performed by Hydrogeo concluded there are links with groundwater that flows on Ayn.

Eocene sinkholes group nearby Qaser-Libya city. Consist of four sinkholes with depth 40-110 meter and one shaft cave with 130 meter depth. Three of sinkholes and Shaft cave are lined in as results of structure effect. Abraq Nutah doline lakes. Group of three sinkholes two of them are consider as doline lake with 39 meter depth at Eocene rock formation.

**Biggest Sinkhole**

Hawa Ahijri is consider as the deepest sinkhole with 230 meter and 214 meter diameter.

Abraq Nutah
Ph. Hassan Elmdawi


Distribution of sinkholes at Kawifyah from Google Earth

## MARINE CAVES

The coastline between Dernah city and Tilmetha cityin Al Jebel Akhdar region are abounded of marine caves due the tectonic condition of area.

The well-known marine caves are haqfet marym, and Noras cave formed in upper cretaceus rocks and Ghandels Cave in Eocene rocks.

Ahsaien Cave
Ph. Saned Alahlafi

## ARTIFICIAL CAVES

During human history many civilizations chose to have settlement which were established at Libyan mountains caves such Jebel Akhdar, Jebel Nefusa, and Jebel Acacus, the number of these caves is difficult to count. Prehistory era exist at a number of caves in the country.

## NATIONAL CAVING ORGANIZATIONS

Libyan National Speleology Organization established January 2021 is considered the only body that deal with caves which is non-governmental organization.

## SPELEOLOGISTS:< 10

## BIOSPELEOLOGY

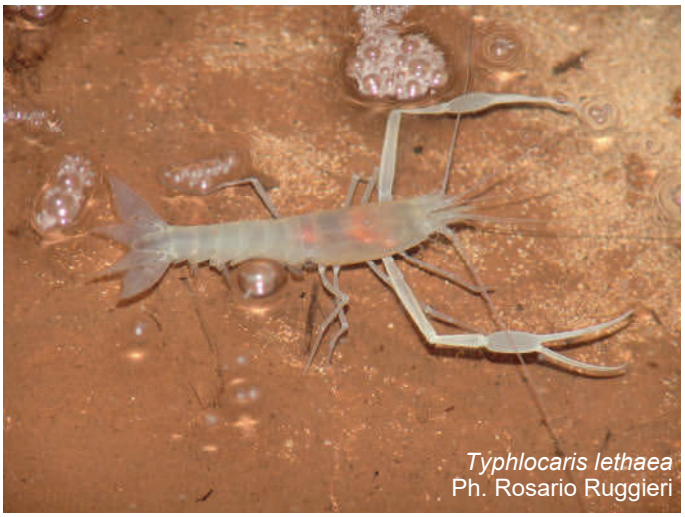
During the speleological research campaign carried out by CIRS Ragusa in January 2007, in the first branch of the lake of the Lete cave (Bengasi), fed by an underground brackish water, in some sections, a few meters from the platform-imbarcadero (structure built during the Italian colonization for a touristic use of the cave), on the sandy-muddy bed, several specimens of *Typhlocaris* have been observed attributable to the species *Typhlocaris lethaea* already found and studied by Parisi (1921) in the same cave. It is a rare Decapod Crustacean, anophthalmic stygobiont (ocular peduncles without eyes) and depigmented which, despite moving on the lakebed quite quickly, allowed us to film and photograph it, considering the clarity of the water. The observed specimens were over 5 cm in size. The *Typhlocaris* genus, in addition to *lethaea*, includes 3 other species, with geographical distribution in the Mediterranean basin, listed below (Tsumamal, 2008; Guy-Haim et al., 2018):

* *Typhlocaris galilea* the first described by Calman in 1909 found in the lake of Tiberia in Israel;

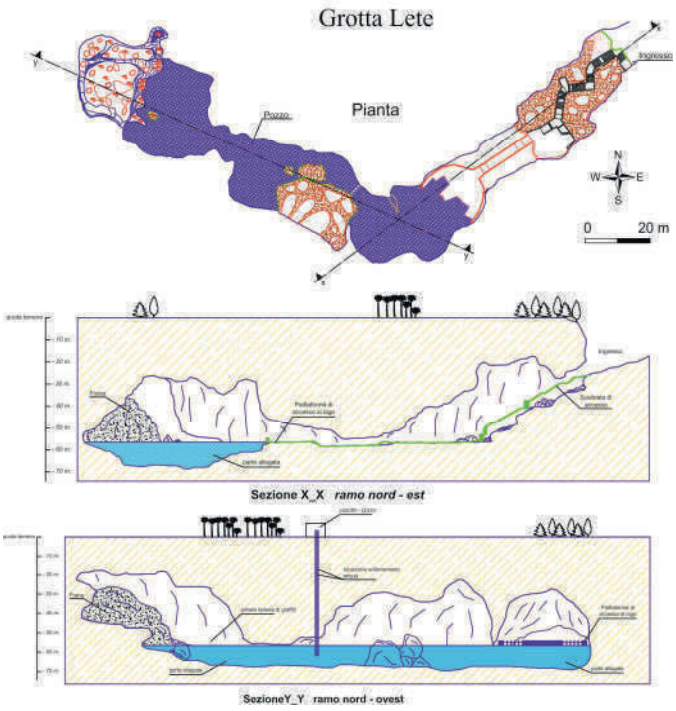
* *Typhlocaris salentina* found and described by Caroli in 1923, in a cave near Otranto in the Salento peninsula in Italy;

* *Typhlocaris ayyaloni* Tsumamal, 2008 from Israel.

Haqfet Mnikharat nearby Almarj city
Ph. Belkasem Alkaryani



*Typhlocaris lethaea*
Ph. Rosario Ruggieri




Survey by CIRS Ragusa

Ahrishieh Cave
Ph. Abdallah Alshalwi

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# MALTA

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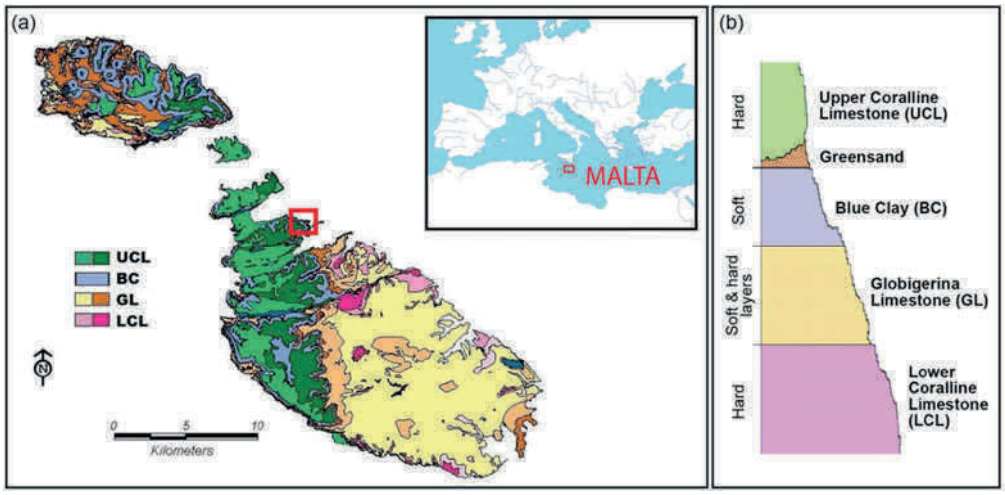
Dwejra, Gozo
Ph. Hans Friederich

## GENERAL INFO

**Republic of Malta**: Malta, Gozo and Comino are the three main islands of the Maltese Archipelago, located in the middle of the Mediterranean Sea, situated about 96 km from Sicily and 290 km from North Africa. The islands represent the only currently emergent part of an extensive shallow-water shelf that extends from Eastern Sicily to the Malta Graben, an important part of the threshold separating the Western and Eastern Mediterranean basins. Limestones and clays of Oligocene and Miocene epochs form the Maltese Islands. The sequence of the marine sedimentary rocks of the Maltese Archipelago is composed of five main geological formations whose oldest formation is Lower Coralline Limestone (LCL) of Oligocene age (Chattian).




Geology of the Maltese Archipelago: (a) geology map, position of the Maltese Islands in the Mediterranean Sea and location of the Selmun Promontory in Malta (in the red frame); (b) sketch of the sedimentary sequence. In: Roberto Iannucci, Salvatore Martino, Antonella Paciello, Sebastiano D'Amico, Pauline Galea, Engineering geological zonation of a complex landslide system through seismic ambient noise measurements at the Selmun Promontory (Malta), *Geophysical Journal International*, Volume 213, Issue 2, May 2018, Pages 1146–1161, https://doi.org/10.1093/gji/ggy025

The Globigerina Limestone Formation is the predominant bedrock in the central and south eastern parts of the island of Malta while the northern and north western parts are characterized by outcrops of the Blue Clay and the Upper Coralline Limestone Formations. The surface geology of Gozo is more varied with the Blue Clay Formation being a prominent outcrop.

The Maltese Islands are characterized by well-developed karst phenomena which result in truly dramatic landforms. Several dolines as well as many caves can be found in the uppermost geological layer, the Upper Coralline limestone. The Lower Coralline hosts archaeologically important caves, sinkholes (il-Maqluba, Malta) as well as some spectacular natural arches (Blue Grotto in Malta). Inland, this rock type forms barren, karstified limestone platforms (Taen, Gozo). Far less karstified compared to the previous limestone formations, karstic channeling and cavities are found mostly where the Globigerina outcrops. Being used as the favoured building stone, atmospheric weathering of the Globigerina limestone results in its typical honeycomb features that add an equally dramatic touch to facades and bastions (defense walls built during the times of the Knights of Malta).

The sinkhole found at il-Maqluba (Malta) merits special attention as it is an important example of how the mixing of seawater and freshwater may accelerate the dissolution of the carbonate rock. The water catchment is restricted a small radius around the sinkhole, and hence natural runoff alone cannot logically explain its impressive size. In all probability, the bottom part of the sinkhole is in direct communication with seawater along one or more underground conduits running below the valley known as Wied Babu. The Blue Grotto is found at the exit of this valley and can be accessed from the sea by boat. This cave also coincides with the location of a temperature anomaly in the seawater.(Source Unit 4 – Karst Heritage Dirk De Ketelaere, Josianne Vella and Anna Spiteri)

## NUMBER OF REGISTERED CAVES: 22

The Maltese Islands, being almost entirely composed of limestones of Oligo-Miocene age, have an abundance of partially sub-merged (hereafter 'emergent') and sub-merged marine caves with divergent geomorphological characteristics.

**Malta** with a total area of 246 km$^2$, is the largest island in an archipelago in the central Mediterranean, is located east of its sister islands of Gozo and Comino. It lies on the Malta plateau, a shallow shelf formed from the high points of a land bridge between Sicily and North Africa that became isolated as sea levels rose after the last Ice Age. Malta is therefore situated in the zone between the Eurasian and African tectonic plates.

The main known cave in Malta is Ghar Dalam near Birzebbugia, it is a fully developed tourist attraction.

**Gozo** is much smaller than the main island of Malta, covering an area of only 64 km$^2$. There are numerous caves on the island, all of which are formed in limestone.

**Comino** is the smallest of the three islands and has reported coast caves and is mostly sheer limestone cliffs, and dotted with deep caves. Some were popular with pirates and marauders during the Middle Ages, as staging posts for raids on hapless boats crossing between Malta and Gozo. The bigger caves are located near Santa Maria Bay on the northern coast.

Ghar_Dalam
Ph. Frank Vincentz

## MOST IMPORTANT CAVES

**Għar Dhalam - The Dark Cave - The Cave of Darkness - Elephant Cave**

Għar Dalam is one of the most important caves in Maltese prehistory because it contains an uninterrupted sequence of fossiliferous deposits extending from the Late Pleistocene to Modern times, a period of 130,000 years. The Neolithic Age 5000 to 4500 BC is represented by pottery. The cave was one of the sites used by early man who crossed to the Maltese Islands from Sicily via a land bridge around 5000 BC.

The site forms part of the Natura 2000 network of protected sites which includes Special Areas of Conservation (SAC) of International Importance and Special Protection Areas (SPA). This conservation status is due to a small population of endemic cave woodlouse, *Armadillidium ghardalamensis*, and a roosting site for the Lesser Horse-shoe Bat, *Rhinolophus hipposideros*.

**Għar il-Friefet (Bat Cave)**

Situated in the same valley as Ghar Dalam, the cave consists of two levels, an upper and a lower level which are shown as 'Level I' 'Level II' respectively. Both levels are found within the Lower Coralline Limestone, which outcrops along the bottom of the valley called Wied Dalam. This formation is overlain by the Globigerina Limestone, which outcrops above the latter part of the lower level. The area covered by scheduling, i.e. the area which was deemed to 'protect' the cave from development, proved to have been defined outside the actual location of the cave. Instead, the entire cave complex has been covered by residential development and roads.

**Ghar il-Kbir**

Ghar il-Kbir (the Great Cave) is the best-known of these settlements. It consists of eight smaller caves, on two different levels, surrounding a large natural cavern. The roof of the cavern a 'karst hollow', has collapsed. The cave dwellers inhabit the smaller caves, having built stone walls inside as well as at the entrance, to separate their living quarters. There is no evidence of wall painting ,which is found at some other sites, but there are various works in stone, loops in the ceiling, ducts, shelves and niches, which evidently served practical purposes. Misrah Għar il-Kbir is a typical example of a karst feature settlement in Upper Coralline Limestone.

**Għar Ħarq Ħammiem**

Ħarq Ħamiem cave is a large submerged terrestrial cavern in the St. Georges Area - Malta. Today it is threatened by a large hotel development. Harq Hammiem Cave (Ghar Harq il-Hammiem) is the only known fully submerged terrestrial cavern in the Maltese Islands. The cave has two chambers on different levels, with an interconnecting narrow corridor leading from the upper chamber to a fully submerged lower chamber. The surface of the water is at a depth of 16 metres below sea level, with maximum depth of 52 metres below sea level. The water inside the cave approximates freshwater at the surface, turns brackish with depth and has seawater characteristics at deeper levels. The cave is inhabited by the rare albino shrimp.

**Calypso Cave**

Calypso Cave is actually a rock fall, and not a real cave that has gained relevance as is said to be the place where Odysseus was a prisoner of love for seven years. He was imprisoned by Calypso, who promised him immortality if he would stay with her. But he escaped, as soon as he had the possibility and returned to his wife Penelope. In Greek mythology Calypso is the daughter of the titan Atlas, she was a nymph living on the magical island of Ogygna.

**Billinghurst Cave**

The largest sea cave on the island of Gozo, located in the cliffs on the north side of the island. The under water tunnel extends for 60 m to an upwards slope leading to second large cave with a large air pocket totally enclosed in rock. The ceiling of this cave is about 5 m above the water level while the furthest walls are approximately 35 m away.

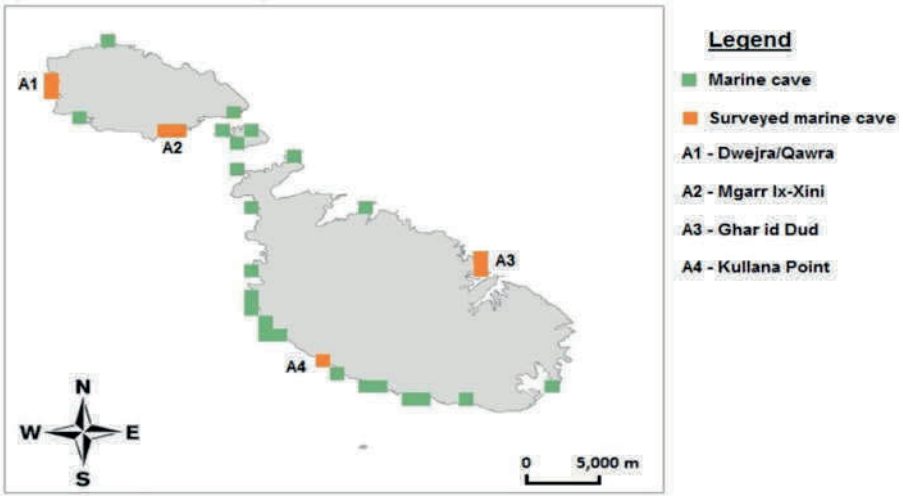
**Inland Sea**

The cave connecting the "Inland Sea" with the Mediterranean was formed as a karst cave during the last cold phase of the Ice Ages. Blue clay is the foundation of the limestone, and is impermeable to the ground water. The water flowed above the impermeable layer towards the sea, using pre existing fault lines and forming caves. When the climate became warmer, the ice caps and glaciers melted and the sea level rose world wide, even in the Mediterranean. So the formerly

normal karst cave was filled with sea water flowing into the cave from the lower end. A collapse of the ceiling, a doline, now forms the famous pool of sea water.

## MARINE CAVES: 42

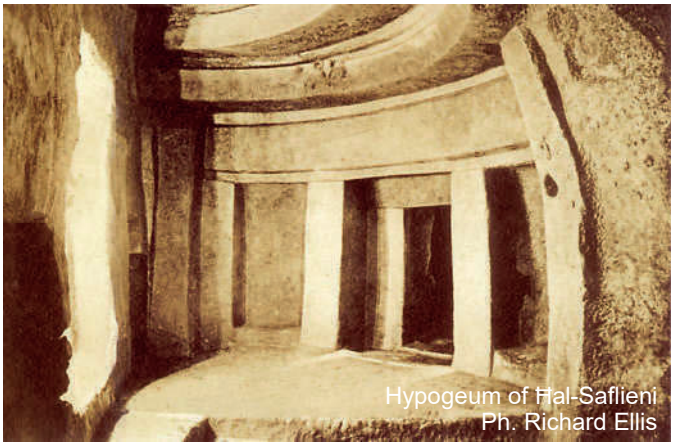
The best-known submerged marine caves are those located within a water depth range of between 10 m and 40 m, which are accessible to divers. These include caves around Gozo, at Dwejra, Wied il-Ghasri, Reqqa Point, Hondoq ir-Rummien and Mgarr ix-Xini; around the Santa Marija area and on the western coast of Comino; and around Malta, at Anchor Bay, Qawra and along the south western coast of Malta. The cave at Reqqa Point in Gozo is the only cave known locally from waters that are deeper than 40 m; however, it is likely that others located at such water depths may be present along the south western coast of Malta and Gozo. Martineau (1965) studied marine terraces in Malta and found concentrations of these features at depths of ca 9.5 m, 17.5 m, 25 m and 33.5 m, which were interpreted as the results of past sea level low stands; caves were reported associated with these terraces, but were not studied. Indeed, there have been no systematic studies on these habitats and their associated species. The little information that is available is incidental, mostly generated in the frame of studies that form part of assessments of environmental impacts, and which may not be easily accessible to the scientific community. There is even less information on the relationships between cave biota and environmental factors (Knittweis, L., et al. 2015).




This map of the location of marine caves in the Maltese Islands was recently published in the Maltese Marine Strategy Framework Directive (MSFD) Benthic Habitats Initial Assessment, based on surveys carried out by Thibaut (2011), and information published in diving and snorkeling guides (MEPA 2014).

## ARTIFICIAL CAVES

In the Maltese Islands, caves have been used since antiquity. Excavations at Ghar Dalam gave pottery dating back to the Neolithic, while the hypogeum at the Xaghra Stone Circle originated as an underground cave. Evidence for cave use has been found for the Bronze Age (Il-Qlejgha), the Roman Period (Ghar ta' l-Iburdan) and has been proposed for the Phoenician Period (Ghar is-Sigra). The use of caves as a dwelling place in the medieval period is a phenomenon of considerable interest, various natural recesses on the islands together with a number of tombs were converted into the abode of medieval troglodytes.



Hypogeum of Ħal-Saflieni
Ph. Richard Ellis

| Site name | Brief description |
|---|---|
| **Binġemma** | Binġemma underground city, located between the Our Lady of Itria Chapel and the Victoria Lines in the Binġemma valley. |
| **Ħal Saflieni Hypogeum** | The Hypogeum is an enormous subterranean structure excavated c. 2500 B.C., using cyclopean rigging to lift huge blocks of coralline limestone. Perhaps originally a sanctuary, it became a necropolis in prehistoric times. UNESCO site. |
| **St Agatha's Catacombs** | The Maltese Catacombs were never meant to be hiding places during persecutions or as living quarters. They were underground cemeteries dug in the globigerina limestone, consisting of long narrow corridors with tombs on each side and vaults. Some of the tombs are even decorated with reliefs and frescoes. These extend to 4100 square metres and date to the 2nd and 3rd century AD. In Rabat, there are over 500 graves of several types, the majority of children. There are sections for pagans and Jews, as well as for Christians. |
| **St Paul's Catacombs** | The catacombs form a typical complex of interconnected underground Roman cemeteries that were in use up to the 7th, and possibly the 8th centuries AD. They are located in the zone of Ħal Bajjada in Rabat, which at times is also known as Tad-Dlam. The area is littered with more than 30 hypogea, of which the main complex, situated within the St Paul's cluster, comprises an intricate system of interconnected passages and tombs that cover an area of well over 2000 square meters. |
| **St Augustine's Catacombs** | Located in the area of Ħal Bajjada, Rabat, the site must be viewed within the context of the other nearby catacombs, such as St Paul's and St Agatha's, which would have originally formed part of the same burial ground. |
| **St. Cataldus Catacombs** | A small set of catacombs that lie beneath the church Saint Cataldus in Rabat, the bishop of Tatanto in Apulia and a rather obscure Irish saint propagated by the Normans. |
| **St Paul's Grotto Rabat 2nd World War Air Raid Shelters** | The Grotto of St Paul, below the adjoining Chapel of St Publius. |
| **Ta' Bistra Catacombs** | A largest set of tombs and catacombs in the city of Mosta. They were first recorded in the late 1800s but were only investigated in 1933 by Captain Charles Zammit, before part of the site was covered over by a new road leading down to Burmarrad. |
| **North Cave** | The cave was discovered in 1949, it is very likely to have originally been a rock-cut tomb but, during the "Tarxien" phase (c3000-2500 BC), it might have served as the temple's rubbish pit. In fact, a lot of material from this phase was found in it, as well as a few pottery sherds of the "Ggantija" phase (c3600-3000 BC), fragments of a human skull and some animal bones. |
| **Tal-Mintna Catacombs** | Tal-Mintna Catacombs, in the village of Mqabba, are a complex of three initially unconnected hypogea. There are numerous more similar small clusters in the area. All have typically small galleries and oven shaped tombs on both sides of the passageways. |
| **Salina Catacombs** | The Salina Catacombs are a cluster of small catacombs located near the Church of the Annunciation in Salina, Naxxar, they are an important record of the sizeable community that must have lived in the area in around the last half of the first millennium AD |
| **Valetta Lascaris War Rooms** | There are many passages in Valetta, but the most famous is the Lascaris War Rooms, a museum in the rocks underneath the city. This complex housed the Fighter Sector Operations Room used during the Battle for Malta 1940-43 along with other operation rooms and ancillary facilities. After the end of the war it was used by NATO up to 1977 to track the movement of Soviet submarines in the Mediterranean. |
| **Mellieha Air Raid Shelter** | A complex of tunnels and chambers under the city that was used as a shelter during World War 2 |

There are hundreds of catacombs in Malta, principally found in the neighborhoods of Citta Vecchia, the old capital of the Island. The catacombs are very small, but are in good preservation. Many of the catacombs were included on the Antiquities List of 1925.

There are tombs cut into the rock (the most extensive ones are the catacombs in Rabat and World War 2 underground shelters in many villages.

## NUMBER OF SPELEOLOGISTS: 3

## REFERENCE RESEARCH BODIES FOR CAVES AND KARST:

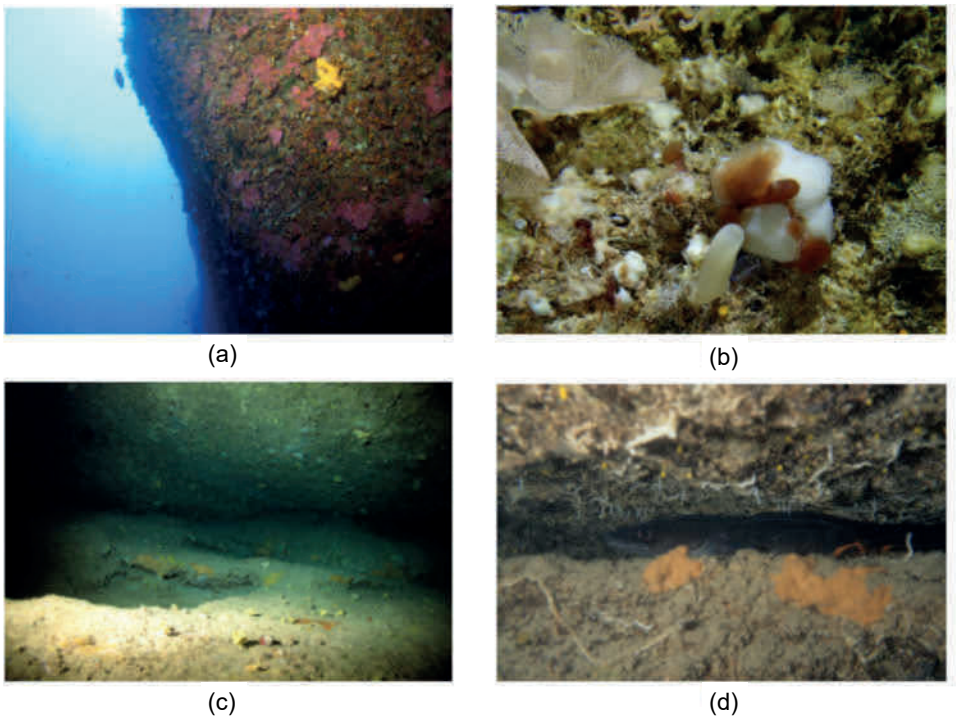
- The University of Malta has a Geography Department, and their archeology units have explored some of the shallow caves for artifacts.
- The National Museum of Natural History does research on bats https://heritagemalta.org/

## BIOSPELEOLOGY

Ghar il-Friefet Cave is primarily important because of the resident fauna described therein. The cave complex has been described to have a large colony of bats belonging to the species *Myotis blythi* (Savona-Ventura, 1984a/1984b). In the mid-1970s, this bat colony was estimated to number about 100-150 individuals. The high pile of bat guano in Cavern 5 suggests that the colony had a particular preference to this roosting site.

This species of bat has since been assigned by a number of mammalogists to the subspecies *punicus* distributed in Malta, Sardinia, Corsica and the Maghreb. Others have assigned this species to the subspecies *omari* distributed in Malta, Crete, Sardinia, possibly Corsica and the Near and Middle East. Others consider the island races of this species to be only superficially similar due to convergent evolution under similar insular environments (Schembri, 1996).

A long-term survey of Ghar Dalam's Cave biota and ecology lasted almost four years and involved several visits to the Cave. During these excursions a number of important observations and collections were made. Particular interest are the new records made from the Maltese Islands (marked in the Faunal and Floral list) and the discovery of a larval case (from which later emerged in captivity the moth *Proterospastis merdella*) in association with a spider's web within the Cave. The case of this moth was not previously known to science and its association with caves is also a new record. The present-day fauna of Ghar Dalam is most abundant in Section I and to a lesser extent in Section II. Both regions are very well illuminated by natural light from the semi-circular entrance of the Cave and are well protected from rain, wind and direct sunlight. Such conditions represent a happy medium between the outside world and the cave environment proper. Although some of the specimens recorded in the fauna I list are occasionally or generally encountered in caves, none of them is a species or variety developed through living inside Ghar Dalam (Zammit-Maempel G.1985).



(a) (b) (c) (d)

Typical biocoenotic characteristics of marine caves found in the Maltese Islands: a. Cave entrances where light penetrates and allows for the growth of algae (photo: T. Perez); b. Semi-dark cave middle sections which are dominated by massive and erect sessile invertebrates (photo: P. Chevaldonn´e); c. Completely dark cave parts which are mostly devoid of sessile macrofauna (photo: T. Perez); d. Example of mobile macrofauna together with sessile fauna (photo: J.A. Borg); (Knittweis, L., 2015).

## MARINE CAVES BIOLOGY

Species characteristic of caves in the Maltese Islands are in agreement with ones recorded from marine caves located on the Salento

Peninsula of southern Italy: all species of sessile benthos, with the exception of just two species (*Zonaria tournefortii* and *Fasciospongia sp*.), were identified by Bussotti et al. (2006). During a study of fishspecies Bussotti and Guidetti (2009) found that the cardinal fish *Apogon imberbis* was by far the most common fish species recorded both at cave entrances and inside caves; Denitto, Moscatello and Belmonte (2009) found the boxer shrimp *Stenopus spinosus* and the majoid crab *Herbstia condyliata* , in rocky walls of caves in spring/summer and winter/spring respectively. *Plesionika narval* may seasonally form large swarms in some marine caves during the day, with up to thousands of individuals covering cave walls (Ott & Svoboda, 1976; Wirtz & Debelius, 2003). Cave dwelling mysids have been extensively studied in recent years. Hemimysis is the dominant genus of mysids found in Mediterranean marine caves, but other species belonging to the genera Siriella and Harmelinella are also common (Ledoyer, 1989). Only Hem*imysis margale* had previously been reported from the Maltese Islands (Rastorgue et al., 2014). The 2012 cave surveys provided the first records for the Maltese Islands of two other mysid species, *Harmelinella mariannae* (Chevaldonne et al., 2014) and *Siriella gracilipes*. All three are amongst the five most common species of cave-dwelling mysids in the north western Mediterranean Sea (Rastorgueff, P. A et al, 2011). Mysids have been shown to form dense swarms of over 10 million individuals in a single cave (Coma, Carola, Riera & Zabala, 1997; Passelaigue & Bourdillon, 1986) and recent research has shown that they are important vectors of organic matter from the outside euphotic zone to the various areas inside caves, since some of these organisms frequently migrate outside caves during the night (Rastorgue et al., 2011). (From: Knittweis, L et al, 2015. Xjenza Online, 3:153-164).

## LEGAL STATUS OF CAVES AND PROTECTION RULES

Malta has established a well-developed legal framework and a set of institutions in the environmental field that have protected ecological, archaeological and built heritage as well as landscapes. Public investment in the conservation of historic buildings, fortifications and archaeological sites has also markedly increased over the past decade, due to increased awareness and the availability of EU funds. There has also been considerable investment in establishing the necessary infrastructure to reduce pollution, particularly in waste management and sewage treatment. Further investment is required in sustainable projects for generating energy from renewable sources. However, in many instances the environment is still seen as a competitor against development. Sustainable development necessitates a shift whereby develop-

Blue Grotto
Ph. Bengt Nyman

ment gradually works with and safeguards the environment and the natural resources it requires. Given the lack of dedicated scientific surveys on cave marine habitat in Malta, and the fact that European Union Member States are required to designate 'Special Areas of Conservation' (SACs) to safeguard this habitat under the 'Habitats Directive' (Council Directive 92/43/EEC, 1992), there is therefore an urgent need for enhancing knowledge of the diversity of marine caves. Submerged or partially submerged sea caves: this habitat type (code 8330 in Annex I of the Habitats Directive) includes caves that are situated under the sea or opened to it including partially submerged sea caves. Their bottom and sides harbour communities of marine invertebrates and algae. (LIFE BaĦAR for N2K project: https://lifebahar.org.mt/).

Caves cover a small length of the coastline within Site of Community Importance MT0000101 (Żona fil-Baħar bejn Rdum Majjiesa u Għar Lapsi). A total of five fully submerged caves and six semi-submerged caves are present, supporting very diverse assemblage's characteristic of semi-obscure caves. The macrofaunal component of this assemblage type consists of a large number of bryozoans, sponges and serpulid polychaetes. The submerged caves, mostly located in the northern half of the site, have a very complex physiognomy and a bottom characterized by fine sediment. The largest of these appear to be two caves lying below the shore of Il-Ħofra ta' Birwin and Iż-Żerqa area. The emergent caves, which are distributed throughout the area, also have a very complex physiognomy, both underwater and above sea-level. The bottom inside the emergent caves consists of bedrock, with small boulders, cobbles and pebbles present in some places. Two fully submerged caves are present below the shore on the western side of the inlet at Site of Community Importance MT0000104 (Żona fil-Baħar bejn Il-Ponta tal-Ħotba u Tal-Fessej - Għawdex), supporting typical cave species, for example the stony sponge *Petrobiona massilliana*. Partially submerged caves are known to occur in Site of Community Importance MT0000105 (Żona fil-Baħar bejn Il-Ponta ta' San Dimitri, Għawdex) mainly along the coast of the island of Comino, however no quantitative data is available (https://lifebahar.org.mt/habitats-targeted-by-life-bahar-for-n2k/).

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# MONTENEGRO

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Djalovica Cave
Ph. Marek Audy and Richard Bouda

## GENERAL INFO

The term karst is more strongly connected to the relief of Montenegro than to any other region. Karst (area of stone) is a term for which there are many synonyms (kras, etc.). It represents a set of landforms and characteristic phenomena and water flows in carbonate rocks (Radojičić B. 1996). Carbonate rocks are mostly made up of two types of rocks: limestone with over 50% $CaCO_3$, and dolomite with over 50% $CaMg(CO_3)$ 2 as well as various other rocks that are formed with impurities of various elements, but they are largely based on the aforementioned two types of rocks.

The territory of Montenegro belongs to the southeastern part of the Dinarides, which has a very complex geological-lithological basis, on which the influence of the erosion process has left a deep mark and conditioned the formation of a very dynamic relief with special emphasis on speleological objects. Basically, the relief of Montenegro can be divided into outer and inner parts (according to the division of the Dinarides). The outer part is a geospace of deep karst, and the inner geospace is fluvio-karst and fluvio-glacial relief. The main characteristic of the relief of Montenegro is that in a very small geospace there are very large altitude differences, which we see from the following: "Of the total area of Montenegro (13,812 $km^2$) only 10% of the land is up to 200 m above sea level, 35% is between 200 and 1,000 m above sea level, 40% is between 1,000 and 1,500 m above sea level, and the remaining 15% is over 1,500 m (Radojičić B. 1996).

## GEOTECTONIC RELATIONS WITH A LITHOLOGICAL BASIS

The territory of Montenegro is divided into seven geotectonic zones, all of which have recorded formed speleological objects:

- The Adriatic zone,
- The zone of paraautochthonous and coastal flysch,
- The Budva riviera,
- The deep karst zone,
- The Kucka onlay,
- The Durmitor onlay,
- The Pljevlja onlay.

**The Adriatic zone** is a continuation of the old African mainland, which builds the Adriatic Sea basin. Between this old

Skadar (karst lake)
Ph. Marek Audy and Richard Bouda

Crvena stijena
Ph. Goran Barovć

Adriatic mass and the Dinarides, there is a fault 10 km from the coast, in the northwest-southeast direction, which is the cause of large seismic activity in this geospace. It is basically built of old basalt rocks over which younger sediments are deposited, which in this geospace form a solid crust about 20 km thick.

**The zone of paraautochthonous and coastal flysch** has the appearance of a syncline that covers geospace in Montenegro from the border with Albania, ie. from the river Bojana, enclosing the Ulcinj and Bar areas, it is underlined below the Budva zone and reappears in the Grbalj field, enclosing the Luštica peninsula. Below the sea surface is a large part of this zone that runs parallel to the coast. It is basically formed by Cretaceous sediments over which limestone and flysch from the Eocene have been deposited, while in some places there are flysch from the Oligocene and Miocene.

**The Budva riviera** is of a very complex composition and is dominated by clastic rocks, and the rest consists of those of carbonate composition. The age of sediments from this zone ranges from Verfen to Eocene. The geospace of Budva, and somewhat south of it, as well as the geospaces around Kotor and Herceg Novi are also built by the sediments of this zone.

**The deep karst zone** is built of Mesozoic limestone, and extends between the Budva zone in the south and the Kucka ridge in the north. It is bordered by the mountain massifs of Orjen, Lovćen, Sutorman, Rumija, Garač, Budoš, Lisca,

Obodska Cave
Ph. Marek Audy and Richard Bouda

Njegoš and Somina. In the geospace of this zone we can follow the syncline that extends in the direction Duga - Niksic field - Bjelopavlic plains - Podgorica-Skadar basin, and the anticline Cetinje - Trešnjevo - Vilusi.

The geotectonic zone of the **Kucka onlay** consists of the anticline Golija - Vojnik - Maganik - Prekornica, which is built of carbonate rocks and shales. Slate and eruptions in the geospace of this zone were discovered in Nikšićka Župa, and their age ranges between the Permian and Cretaceous periods.

**The Durmitor zone** is built of Durmitor flysch, Mesozoic limestones as well as eruptives and shales. This zone consists of the anticline Durmitor - Sinjajevina - Bjelasica - Komovi - Prokletije. Drilling to great depths has shown that this zone is largely dragged over the Kucka zone.

**The Pljevlja zone**, to which the extreme northeastern parts of Montenegro belong, was previously built of Paleozoic and Verfen shales - sandy and clayey sediments of flysch-like structure (Radojičić B. 1996). At higher mountain heights, Mesozoic carbonate rocks can be found in this zone.

## MAIN RELIEF UNITS

Relief regionalization of Montenegro can be found in several research papers, however, the one in which the specifics of karst are particularly pronounced was done by B. Radojičić. According to this regionalization, the following areas stand out in relief on the territory of Montenegro:

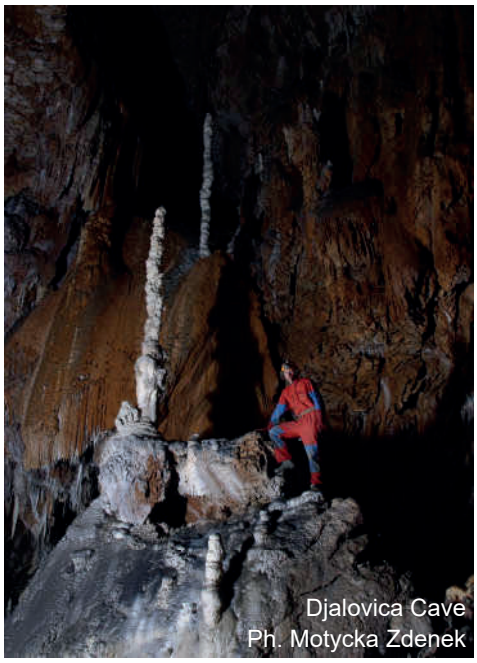
- Montenegrin coast,
- The deep karst zone,
- The valley of central Montenegro,
- Area of high mountains and plateaus
- Northeast Montenegro.

**The area of the Montenegrin coast** is very clearly separated by the mountain range Orjen - Lovćen - Sutorman - Rumija. This is a very narrow zone by the sea, in whose geospace there are several smaller extensions, next to Herceg Novi (Sutorina), Tivat (Grbaljsko polje), Budva, Bar and Ulcinj. The coast is very poorly indented, except for the Bay of Kotor, which clearly stands out as the only large bay. Speleologically, Orjen and Lovćen are well researched, while Rumija is

Kacunova Cave
Ph. Marek Audy and Richard Bouda

still a poorly explored area.

**The area of deep karst** or the area of Old Montenegro is quite well separated from the rest of the geospace. Towards the Montenegrin coast, the border is the mentioned mountain range (Orjen - Lovćen - Sutorman - Rumija), while the border of this region towards the valley of central Montenegro is the mountain range Garač - Budoš - Zla gora - Njegos and Somina. The western border of this region is not natural and consists of the administrative border with Herzegovina. This area is the most typical karst geospace in the world, where all karst forms are fully developed. The thickness of the limestone layers in this geospace is over 4,000 m. An important characteristic of this area is that there are areas that receive a maximum of 8,000 mm of precipitation for year, which was once the European maximum (Radojičić B. 1996). Despite this amount of precipitation, the curiosity is that there is not a single surface water flow in this entire geospace, and that almost the whole amount of water seeping through the karst base flows away while a small part evaporates.


Djalovica Cave
Ph. Motycka Zdenek

A special form of relief of this geospace is represented by karst fields, of which there are several in this part of Montenegro. The most important are: Cetinjsko field, Njeguško field, Dragaljsko field, Grahovsko field and parts in the Nikšić zone.

Observed from the aspect of the topic being covered, this geospace is very characteristic due to the fact that it receives the largest amounts of precipitation from the entire geospace of Montenegro, and in proportion to that it has a negligible number of surface flows. This conditioned the appearance of a large number of speleological objects that were explored in certain regions. The largest number of locations was explored in the area of Nikšić field, during the construction of the Hydrosystem "Gornja Zeta", but also the northern slopes of Orjen and Lovćen. Other parts are relatively poorly researched and represent a great resource to pay attention to in the coming period.


Slivlje Cave
Ph. Goran Barovć

**The valley of central Montenegro** covers the geospace between Gatačko field in Herzegovina and the confluence of the Bojana and the Adriatic Sea. This is a syncline that slopes slightly northwest-southeast. This valley consists of several smaller areas that are somewhat separate units, and are connected to each other. These are: Udolina Duga - Nikšićko field - Bjelopavlićka plain - Podgoričko - Skadarska basin. According to its hydrographic characteristics, this geospace is characterized by the river Zeta, which drains most of this geospace through its tributaries.

The most characteristic part of this zone is the Nikšić field, which is relatively well researched, but of course, there is room for further research.

**The area of high mountains and plateaus** has a dominant appearance in the geospace of Montenegro. The whole area has the Dinaric direction of extension, while in its southeastern part they turn in the southeast-northwest direction. In this area, two mountain ranges clearly stand out. The first mountain range consists of mountains in whose geological composition are largely limestones, which enabled the formation of a wide range of various karst forms on them, similarly to the area of the Deep Karst. The first range consists of: Golija - Vojnik - Maganik - Prekornica, and the second mountain range: Volujak with Maglić and Bioč - Ljubišnja - Durmitor - Sinjajevina - Bjelasica - Komovi and Visitor - Prokletije. In this part, two areas are clearly distinguished: the area of Pivska mountain and Jezerska area. This geospace is the hydrographic source of the largest number of rivers in Montenegro, as well as the geospace with the most developed river network.

Of all the listed sites, Durmitor has the highest level of research, because international speleological expeditions have been organized there on several occasions. Prokletije also has a certain level of research, noting that foreigners, mostly Poles, dealt with this area, and there is very little or no research data.

**The area of northeastern Montenegro** differs from the rest of the geospace of Montenegro in its lithological composition. “This geospace is mostly built of clastic rocks, Paleozoic shales, marls, marly limestones, hornblendes and eruptives, meanwhile, sediments and allogeneic Quaternary deposits can be found in the valleys of Triassic lake. There is karst in the northwestern parts and in the high mountains (Radojičić B. 1996). The river valleys of Ćehotina, Lim and Ibar have a dominant appearance in this geospace.

This unit has been researched rarely, although the geological basis of the area does not give hope for the formation of some larger objects as there are in other parts of Montenegro.

## ABOUT RESEARCH IN MONTENEGRO

Speleological research in Montenegro has a long tradition. Traces can be found in the records of world-famous fellow travelers such as Rovinski, Martel, Lahner, Gessman, etc. Of the biospeleologists, these must be mentioned: Absolon, Komarek, Knirisch, Kratochvil, Remmy, Pretner, Hadži, Brodar and many others.

Among the institutions that were directly or indirectly engaged in the research of speleological objects, we must mention: the Institute for Geological Research, the Institute for Nature Protection, the Institute for Technical Research, Electric Power Industry of Montenegro, Boksiti Niksic, the Pljevlja Coal Mine, the former Yugoslav Army.

Many clubs and research teams from the region were engaged in speleological research in Montenegro: ASAK - Belgrade, SOB - Belgrade, "Vladimir Mandic Manda" - Valjevo, GI "Jovan Cvijic" - SANU, SGGF - Belgrade, HSS - Zagreb, DISKF - Zagreb, Cave Association of Slovenia - Ljubljana, Center for Karst and Speleology - Sarajevo. Of the research teams from Montenegro, the most significant results were achieved by the Speleological Society Nikšić - Nikšić, and besides it: Pestingrad - Kotor, Biospeleological Society of Montenegro - Podgorica, SUBRA - Herceg Novi and Akovo - Bijelo Polje.

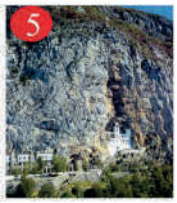
Unfortunately, a large number of reports on speleological research in Montenegro are in the archives of clubs from abroad that are not available to us for various reasons. Some were done in a period when there was no national speleological organization in Montenegro, a national institution dealing with the control of research procedures in Montenegro, there was no legislation according to which all those engaged in this type of research are required to report residence and research. It is known that speleologists from: Poland, Hungary, England, the Czech Republic and Belgium have explored the area of Montenegro from foreign researchers. It is probable that there were researchers from other countries, but we do not have official data that confirms that.

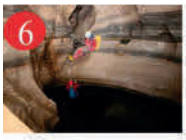
Slivlje cave
Ph. Goran Barovć

# MAP OF IMPORTANT SPELEOLOGICAL OBJECTS OF MONTENEGRO

















| | Name | Tip | The nearest settlement | Locality | An important feature | Length | Depth |
|---|---|---|---|---|---|---|---|
| 1. | Ledena cave | P | Žabljak | Durmitor | Ice crystals | | |
| 2. | Jama na Vjetrenim brdima | J | Žabljak | Durmitor | Depth | | -775 m |
| 3. | Cave in Djalovića klisuri | P | Bijelo Polje | Korita | Jewelry / Length | 20 km | -120 m |
| 4. | Red rock | P | Nikšić | Banjani | Archaeological site | | -30 m |
| 5. | Manstir Ostrog | P | Nikčić | Ostroške grede | Monastery | | |
| 6. | Ponor Slivlje | J | Nikšić | Nikšičko polje | Depth | 155 m | |
| 7. | Manastir Dajbabe | P | Podgorica | Dajbabska gora | Monastery | | |
| 8. | Vranštica | P | Podgorica | Moračke planine | Jewelry | 0,45 km | |
| 9. | Grbočica | P | Cetinje | Trnovo | Length | 2,6 km | |
| 10. | Njegoševa cave | P | Cetinje | Njegiši | Length | 3,3 km | -340 m |
| 11. | Cetinjska cave | P | Cetinje | Cetinje | Length | 1,6 km | |
| 12. | Obodska cave | P | Cetinje | Rijeka Crnojevića | Length | 340 m | |
| 13. | Lipska cave | P | Cetinje | Lipa | Length | 3,4km | |
| 14. | Duboki do | J | Cetinje | Njegiši, | Length / Depth | 2.1 km | -506 m |
| 15. | Blue cave | P | Herceg Novi | Luštica | Marine | 15 m | |
| 16. | Sopot | P | Herceg Novi | Risan | Depth | 110 m | -25 m |
| 17. | Liuta | J | Kotor | Ljuta | Depth | | -120 |
| 18. | Lipci | P | Kotor | Lipci | Archaeological site | | |
| 19. | Iron pit | J | Danilovgrad | Maganik | Depth | 4,1km | -1173 |

Autor: Goran Barović

## NUMBER OF REGISTERED CAVES: 1491

| Longest caves | | |
|---|---|---|
| **Name** | **Region** | **Length (m)** |
| Pećina nad Vražijim firovima | Bistrica, Bijelo polje | 20,000 |
| Dvogrla jama | Lovćen | 7,500 |
| Njegoševa pećina | Lovćen | 6,100 |
| Željezna jama | Maganik | 4,100 |
| Lipska pećina | Lipa, Cetinje | 3,400 |

Djalovica Cave
Ph. Marek Audy and Richard Bouda

| Deepest caves | | |
|---|---|---|
| **Name** | **Region** | **Depth (m)** |
| Željezna jama | Maganik | -1,173 |
| Jama na Vjetrenim brdima | Durmitor | -775 |
| Dvogrla jama | Lovćen | -715 |
| Pala skala | Lovćen | -667 |
| Bunda jama | Durmitor | -657 |

## MARINE CAVES: ~5000

No number determined. Speleological objects in the sea zone are most often created by the work of waves and their formation is in progress. Officially, there is no list of this type of location. The Institute of Marine Biology in Kotor has certain records, although these censuses were made as secondary data.

## ARTIFICIAL CAVES

For now, the total number of artificial facilities is 102, although this number is not final, the construction of a part of the highway from Bar to Boljar is in progress, and only on the section that is being built, there should be 275 tunnels (two-pipe). Out of the total number, 158 are in road traffic, and 117 are by rail. Hydrotechnical tunnels should be mentioned: In the Cetinje field which serves for drainage, the Tunnel in the Gornja Zeta Hydrosystem, which drains water from the Nikšić field near the HPP Perućica, the Vrmac Tunnel which was built along the road and collects water for the water supply in Kotor and the Sozina Hydro Tunnel) within the Regional Water Supply of the Montenegrin coastline.

It should be noted that one object, the Shipčanik Tunnel, once a military facility - a shelter for aircraft, is now used as an exclusive restaurant of the company Plantaže, but also as a wine cellar.

| Cave sanctuaries | |
|---|---|
| **Name** | **Region** |
| Monastery Ostog | Nikšič/Danilovgrad |
| Monastery Dajbabe | Podgorica |

## NATIONAL SPELEOLOGICAL ORGANIZATION:

- Association of Speleological Societies of Montenegro

## NUMBER OF SPELEOLOGISTS: ~100

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: ~10

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST:

- Association of Speleological Societies of Montenegro
- The Speleological society Nikšić
- Pestingrad KOTOR
- SUBRA
- AKOVO
- Biospeleological Society of Montenegro

## BIOSPELOLOGY

According to Pavićevic (Pavićevic et Al 2020):" The Dinarides are recognized as a world hotspot of subterranean biodiversity, and are extremely rich in highly specialized troglomorphic invertebrates, especially insects. Among these, one of the best known and studied groups are Trechinae, especially the morphologically peculiar, so called *Aphaenopsoid* Trechini beetles of the former „série phylétique d´Aphaenops" sensu Jeannel (1928). Up until the end of the 1980´s, four phyletic lines "série phylétique" sensu Jeannel (1928) of subterranean Trechini were known from the Dinaric Karst: *Duvalius*-phyletic line, *Neotrechus*-phyletic line, *Typhlotrechus*-phyletic line and *Aphaenops*-phyletic line. The first of these three lines were represented by a single genus each, while the Aphaenopsphyletic line included three genera; Aphaenopsis G. Müller, 1913 (Central Bosnia), *Scotoplanetes Absolon*, 1913 (southern Herzegovina and Montenegro) and *Adriaphaenops Noesske*, 1928 (Herzegovina, Mon-

*Metellina merianae,* male, Vidrovanska pećina cave.

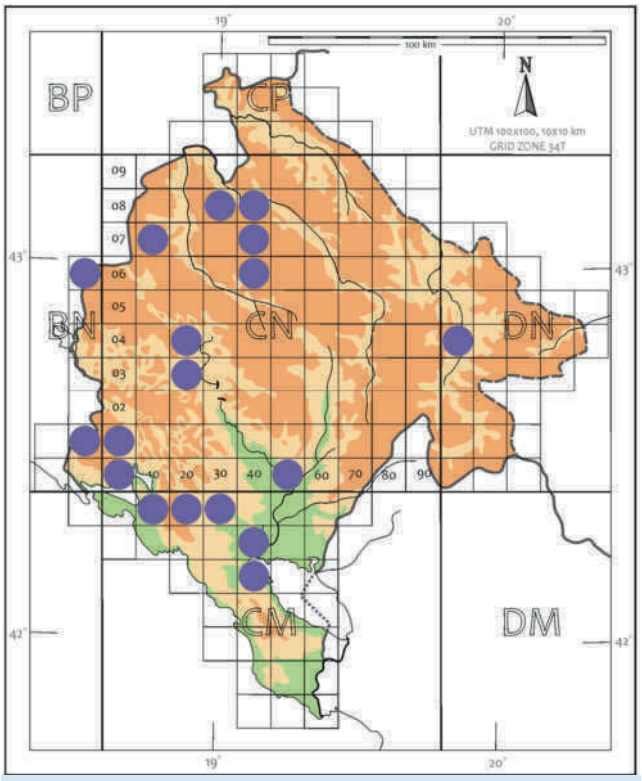
Marjan Komnenov "SUBTERRANEAN SPIDERS (ARACHNIDA, ARANEAE) OF MONTENEGRO " in THE MONTENEGRIN ACADEMY OF SCIENCES AND ARTS PROCEEDINGS OF THE SECTION OF NATURAL SCIENCES, 23, 2019 OF MONTENEGRO

tenegro and Albania). Traditionally, the Aphaenops-line was considered to be “ultraevolved”, “archaic”, or “high or hyper-specialized”, and comprised species with a similar, so called “aphaenopsoid” or “aphaenopsian” habitus, (Pavićevic et Al 2020).

In his study Pavićevic (Pavićevic et Al 2020) describe: one new genus and species of subterranean Trechine beetle, *Orcusiella prokletijensis* gen. et sp. nov. from a high-altitude pit situated on Prokletije Mountains, Montenegro. This new taxon is described, illustrated and compared with closely related taxa. Altogether, the Dinaric subterranean Trechini are now classified into 19 genera, 15 of them endemic, comprising ca 110 described species (Belousov 2017; Lohaj and Delić 2019).

Regarding bats in Montenegro 28 species are reported in the country described in the study Distribution of bats (Chiroptera) in Montenegro: (Presetnik et al 2014).

Presetnik inform that: “the bat observations are concentrated mainly along the Adriatic Sea coast and to the lowland areas around the Skadar lake. However, records of bats are also available from medium altitudes as well as from the high mountain environment. Many species are represented by just a few sightings, and large parts of the country are without any records of even the most frequently observed species. Only 33% of the 10×10 km UTM squares covering Montenegro contain at least one bat record. There are several important summer cave roosts and a few known roosts in buildings, but generally, very little data are available on maternity roosts or hibernacula”. (Presetnik et al 2014).




UTM map of the current distribution of 25 pseudoscorpion species and 4 subspecies in Montenegro (in Ćurčić *et al*., 2016)

Other relevant group that have been studied by Komnenov in Montenegro are spiders, he reports 33 species and 2 subspecies of subterranean spiders (troglobites and troglophiles) from 8 families (Komnenov 2019).

Additional important studies were conducted in 2013-2014, Society for Cave Biology successfully implemented the project “Monitoring of Proteus anguinus by environmental DNA sampling”, in Bosnia and Herzegovina and Montenegro, within a project co-financed by the Critical Ecosystem Partnership Fund, BirdLife International and DOPPS (see project outcomes: https://www.cepf.net/sites/default/files/sg60185-final-report.pdf

Regarding pseudoscorpions based on current knowledge, “it can be stated that a total of 50 species and seven subspecies of pseudoscorpions have been recorded in Montenegro. Out of six pseudoscorpion families and eight genera known in Montenegro, the family *Neobisiidae* (with two genera – *Neobisium Chamberlin*, 1930 and *Roncus* L. Koch, 1873) is the

Obodska Cave
Ph. Marek Audy and Richard Bouda

most abundant (with 34 species and seven subspecies). The pseudoscorpion fauna of Montenegro is characterized by a high degree of endemism (72% of all recorded species and 100% of all recorded subspecies are endemics), as well as by the presence of numerous cave-dwelling forms (58% of species and 57.14% of subspecies). Professor Boţidar P.M. Ćurčić greatly contributed to a better understanding of the biodiversity of this arachnid group in Montenegro. Alone or with collaborators, he erected 52% of all pseudoscorpion species inhabiting Montenegro" (Ćurčić 2016)

In Montenegro have been recently realized a study on the Biodiversity of Fungi in the photic and aphotic zones of Montenegro caves that specifies: "the composition of micromycetes communities was investigated in both photic and aphotic entrance zones of seven caves in Montenegro: Obodska Pećina, Golubinja Pećina, Velustica Pećina, Vrbacka jama, Jama ER-1, Njegoš Pećina, and an unnamed cave. In total, 72 species of micromycetes were identified: 46 species from illuminated photic zones of the caves, including 43 species on phototrophs, 10 species from the air, 15 species on substrates, and 50 species from unlit aphotic zones, including 35 species from the air and 37 species on substrates. (Kozlova 2020).

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## LEGAL STATUS OF CAVES AND PROTECTION RULES

Everything is regulated by the law on nature protection implemented by the Government of Montenegro, the Ministry of Environmental Protection, the Environmental Protection Agency, www.epa.org.me

Đalovića cave
Ph. Željko Madžgalj

# MOROCCO

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Ain D'Anou
Ph. Ayoub Nehili

## GENERAL INFO

Morocco is located in the north-western part of Africa. It is bounded by the Strait of Gibraltar and Mediterranean Sea on the north, by Mauritania on the south, by Algeria on the east and by the Atlantic Ocean on the west. The Moroccan coastline extends over 3,500 km in length. The total area of The Kingdom of Morocco is 710,850 km². Karstic outcrops cover approximately 100,000 km² which is 15% of the entire territory of Morocco. This makes the country one of the most favorable locations for great speleological discoveries in North Africa

The main karst areas in Morocco are located within the Atlas Mountains, the Rif and the Atlantic Mesata.

Presently, Morocco counts for around 1,500 inventoried caves in all the territories, mainly located in Middle Atlas, Rif, Central High Atlas and Lesser Atlas.

Caving exploration started in Morocco around 1927. Until the 1980's, caving activities were done primarily by foreign caving groups during expeditions or by the European cavers affected in Morocco during and after the protectorate. The first Moroccan Caving Club was created in Agadir in 1983. Since then, the number of caving clubs have increased significantly, though exploration activities are still struggling. Today, Morocco has two Federations and some 30 clubs associations. Too many of them though, are not active at all.

The earliest known information about caves in Morocco date back to 1912, where the Achakar and Idoles caves in Cap Spartel has been explored for archeological purposes. The first document that describes a cave from a speleological point of view was made by N. Casteret in 1934.

Today, the only official document which has inventoried Moroccan caves, is "Speleological inventory of Morocco, 1981".

## KARST AREAS

The karst represents one of the most remarkable characteristic landscapes in Morocco which can be found in all structural areas such as: the Rif, the High Atlas, the Middle Atlas, the Anti-Atlas, the Oriental and the Meseta. These karstic manifestations are located within several limestone outcrops that testify the relics of an ancient karstification original from a specific lithological, structural and bioclimatic conditions; thus, these outcrops are represented as follows:

**Limestones and dolomites of Lias**

They represent, by far, the largest karstic complex in Morocco, with an outcrop area of about 30,000 km² spread as follows:

- 2,500 km² in the Oriental (Beni Bou Yahi - Bni-Snassène - Horsts chain and High Plateaux)
- 6,000 km² in the Middle Atlas causse
- 3,500 km² in the Folded Middle Atlas
- 2,000 km² in the Atlas of Beni-Mellal
- 13,000 km² in the High Atlas

The thicknesses of the Liasic limestone series are extremely variable, ranging from a tens of meters to more than 500 meters. Their geographical location is at high altitudes in well-watered domains with an important vegetation cover, where the snow cover remains for several months each year, has enabled the development of various superficial and underground karst features. This has brought it the appellation "water tower of Morocco" in recognition of the important hydric springs that flow from these structures.

**The Middle Jurassic limestones (Dogger)**

They represent some 20,000 km² of exposures. Located essentially in the High Atlas, the Middle Atlas and the Eastern part of the Rekkame plateau, they appear in less homogeneous bodies and are less thick than the

Kef Bouslama
Ph. Ayoub Nehili

Liassic limestones.

**Adoudounian and Georgian limestones (Infracambrian)**

They are exposed over some 18,000 km² of the Anti-Atlasic domain. They are several hundred meters high in the West, thinning rapidly towards the East of the range. The karst displays are moderately developed at the surface in the outcrop areas and probably non-existent at depth according to the drillings.

**The Cenomanian-Turonian limestones**

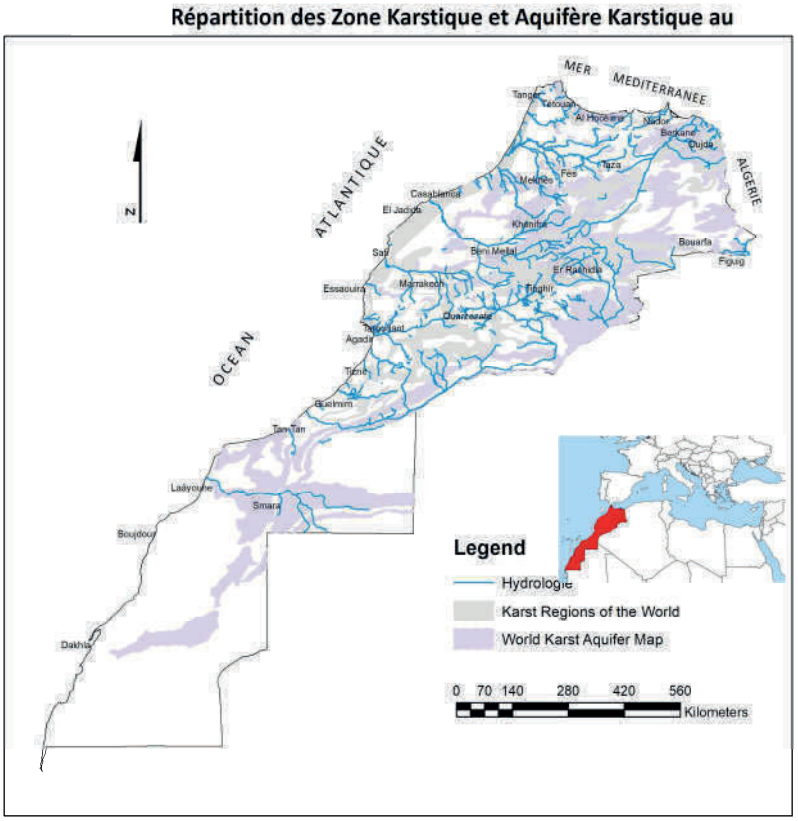
Quite widespread throughout the country but in small groups, they are mainly located in: the Phosphate Plateau, the Essaouira-Chichaoua basin, the Safi-Oualidia Sahel, the South-Atlasic furrow between Errachidia and Boudenib, the Souss valley and the upper Moulouya valley.

**The Plio-Quaternary limestones**

These are sandstone limestones, often shell-bearing or conglomeratic. They are found on the Atlantic coastal zone between Tangier and Tarfaya with a thickness that varies between 20 m and 200 m.

Other Carboniferous formations are also present, but are not very well represented, such as the Carboniferous limestones in Rabat region, upper Jurassic gypseous limestones on the Mouissate hills, Safi region and Ida ou Tanane region, Hauterivian limestones (called Dridrate limestones) located between Safi and El Jadida or Quaternary lacustrine limestones spread in Goulmime-Bouizakarne, Tiznit, Sais and Tadla region.

However, for Moroccan caving, the main karst fields that are suitable for exploration and investigation are displayed on the map.

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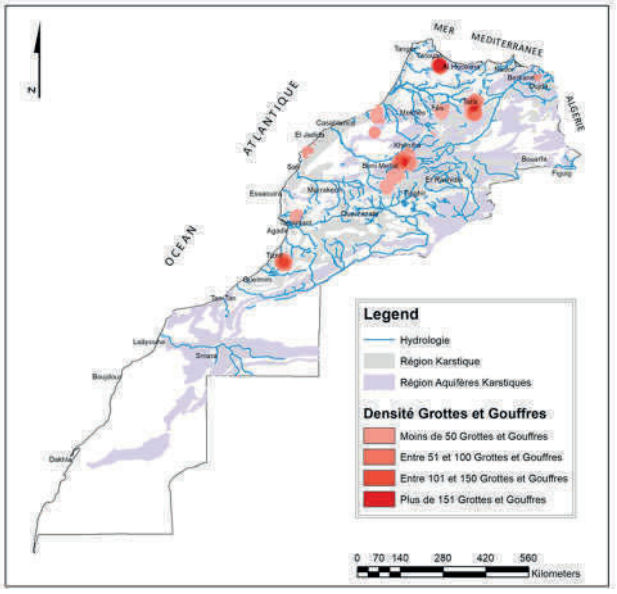
## NUMBER OF REGISTERED CAVES: 1,428

| Longest caves | |
|---|---|
| **Name** | **Length (m)** |
| Win Timdouin River | 19,000 |
| Chaara River | 8,000 |
| Toghobeit | 4,000 |
| Chiker | 3,800 |
| Kef Aziza | 3,500 |
| Ifri n'Taouia | 3,600 |
| Aïn d'Anou | 3,100 |
| Kef d'Ensough | 2,800 |
| Ain Melghfi | 2,700 |
| Ghar Isk n'Zouya | 2,300 |




Distribution of Karstic Zones and Karstic Aquifers in Morocco vs the density of explored of Caves

| Deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| Toghobeit | -722 |
| Tikhoubat | -322 |
| Friouato | -271 |
| Kef Sao | -220 |
| Kef Anfid | -214 |
| Kef d'Ensough | -210 |
| Kef Ouaralagh | -210 |
| Kef Amafane | -190 |
| Taghicht Sidi Mohamed | -170 |
| Kef Ichou Chai | -170 |

## MARINE CAVES

Today, no data exists for Marine caves within the Moroccan caving community, but many divers speak about the existence of marine caves in North of Morocco at the Mediterranean and in the Atlantic Ocean close to Safi and Sidi Ifni. However, many universities researchers have started to be interested by these kind of caves. As result a team from faculty of Sciences and Techniques - Tangier is working on an inventory of coastal caves in the Northeast of Morocco.

Kef Aziza
Ph. Ayoub Nehili

## ARTIFICIAL CAVES

There are many artificial caves in Morocco that may be classified as Mines, Khettara and troglodyte house. Mine information in Morocco are too complex to analyze. Officially, Morocco has 56 important active mines, but in reality, this number should be much higher if we were to count inactive mines. Khettara is an ingenious traditional drainage system to drain water to the cities and for crop irrigation in the southern oasis of Morocco. In the Tafilalet Valey we count around 500 Khettara while in Marrakech there are 567 Khettara. As of today, these tunnels are considered as a real intangible heritage and ingenious ancestral know-how. The last form of these artificial caves are troglodyte house, which can be found in many locations in Morocco. These kind of caves were cited in many old exploration reports and sociology research. The most well-known city with troglodyte is Bhalil.

## NATIONAL CAVING ORGANIZATION:

- Fédération Marocaine de Spéléologie
- Fédération National Marocaine de Spéléologie

The two federations are not members of the UIS.

## NUMBER OF SPELEOLOGISTS:

Morocco has about 100 cavers, but only a few are considered as active cavers.

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS:

There are approximately 30 caving associations located in different cities and regions of Morocco.

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST

There is no reference to research organizations in Morocco. However, many university laboratories conduct research and studies regarding caves.

## BIOSPELEOLOGY

The first Biospeology research in Morocco date dates back to 1869, when Georg Dieck described two species of Coleopera, namely, *Geocharis messiniana* and *Crypharis robusta*. Since then, more research has been carried out leading to the discovery of several other species of different taxons.

The most studied group so far is the **Order Coleoptera** with over 53 species. Generally, the species that are studied are troglophiles or trogloxenes, except in the case of a few strictly troglobial species with complete atrophy of the eyes and a

caramel-colored body (due to the lack of melanins), such as:

• *Apteranillus bichaini* (Perreau & Faille, 2012) at imi Ougoug cave, Agadir Ida-Outanane region.

• *Apteranillus minosianus (*Lecoq & Quéinnec, 2005) in Aïn Melghfi Ouaouizaght underground river in Azilal region.

• *Apteranillus rotroui (*Scheerpeltz, 1935) at Chiker cave, Middle Atlas, Taza.

• *Apteranillus ruei (*Español 1969) and *Torneuma troglodytis (*Stüben 2009) at Aziza cave in Boudnib.

• *Domene (Spelaeomene) camusi* (Peyerimhoff 1949) from the Goran cave, Safi.

• *Domene aurouxi* (Español,1970) from the Ifri El Caïd cave, Azilal.


(a) Apteranillus rotroui, (b) Domene (Spelaeomene) camusi, (c) Tachycampa lépineyi, (d) Agraecina agadirensis, (e) Dysdera caeca, (f) Jeekelosoma abadi, (g) Magniezia gardei, (h) Graeconiscus gevi, (i) Adoniscus soloisensis. (Ph. Moutaouakil Soumia)

**Group of Araneae** with 35 described species, including three particularly troglobies:

• *Agraecina agadirensis (*Lecigne 2020) from the Cave of Bats in the Agadir Ida-Outanane region.

• *Lepthyphantes fadriquei (*Barrientos 2020) and *Dysdera caeca* (Ribera 1993) both in Aziza cave, Boudnib

**Group of Collembola** with 22 species generally troglophiles, such as for example:

*Bilobella aurantiaca* (Caroli, 1910) in Sidi Mjber cave.

*Lepidocyrtus lanuginosus* (Gmelin, 1788) from Ifri El Caïd and Friouato cave.

*Protanura deharvengi* (Thibaud 1980), *Seira squamoornata* (Stscherbakov, 1898) in Bou Rhibab cave near the town of Berkane. (Thibaud & Z. Massoud, 1980)

**Group of Diplopoda:**

• *Jeekelosoma abadi* (Mauriès, 1985)

- *Jeekelosoma heptarachne* (Enghoff & Reboleira, 2019)
- *Jeekelosoma viginti* (Enghoff & Reboleira, 2019)
- *Origmatogona strinatii* (Manfredi, 1956)
- *Ceratosphys maroccana* (Mauriès, 1985)
- *Odontostreptus fadriquei* (Enghoff, 2020)

**Group of Diplura**, count two species mainly distributed in caves in northern Morocco (Chefchaouen region) and in the Middle Atlas:

- *Tachycampa lépineyi (*Silvestri, 1936)
- *Jeannelicanpa stygia* (Condé, 1956)

**Group of Isopoda** with two terrestrial and one aquatic species:

- *Adoniscus Soloisensis* (Vandel, 1955)
- *Graeconiscus gevi* (Garcia et al, 2020)
- *Magniezia gardei* (Magniez, 1977)

The **Order of Chiroptera** is a group of flying mammals, commonly called bats, "Tair el Lile" or "Ouatouate" in Arabic. In Morocco, there are around 30 species that all feed on insects.

In Morocco, bats all belong to the Suborder Microchiroptera and are respectively part of 7 families:

- Rhinopomatidae (2 rhinopomas).
- Emballonuridae (1 taphien).
- Nycteridae (1 nyctere).
- Rhinolphidae (5 rhinolophs).
- Hipposideridae (1 horseshoe and 1 trident).
- Molossidae (2 molosses).
- Vespertilionidae (5 murins, 4 epistrelles, 1 vespère, 3 noctules, 1 barbastelle, 1 minioptera, 3 oreillards).

## LEGAL STATUS OF CAVES AND PROTECTION RULES

In Morocco, there are no official laws that govern and regulates caving and caves.

Nevertheless, several caves already benefit indirectly from regulatory assessments in Morocco. In majority of the cases, it is within the framework of the protection of archaeological and natural heritage sites:

- Arrêté du ministre des travaux publics et des communications n° 707-71 du 06/09/1971 (6 septembre 1971) réglementant les extractions de sable ou de matériaux quelconques sur le domaine public maritime aux environs des Grottes d'Hercule (province de Tanger)
- Décret n° 2-56-664 du 12 safar 1376 (18 septembre 1956) ordonnant une enquête en vue du classement du site des grottes préhistoriques du Cap-Rhir (cercle de Mogador, annexe de Tamanar)
- Arrêté viziriel du 8 safar 1372 (28 octobre 1952) classant le site préhistorique dit “ La grotte aux pigeons ” à Taforalt (région d'Oujda)

Other caves are subject to local customary restrictions, such as the caves which represent sources of drinking water or irrigation for surrounding villages, like:

- Ain Sfa Cave nearby Oujda.
- Ansar Tiouine nearby Chefchaouen.
- Tit Nafri in the valley of Assads nearby Taroudant.

So, among these laws that can govern caves and speleology there are:

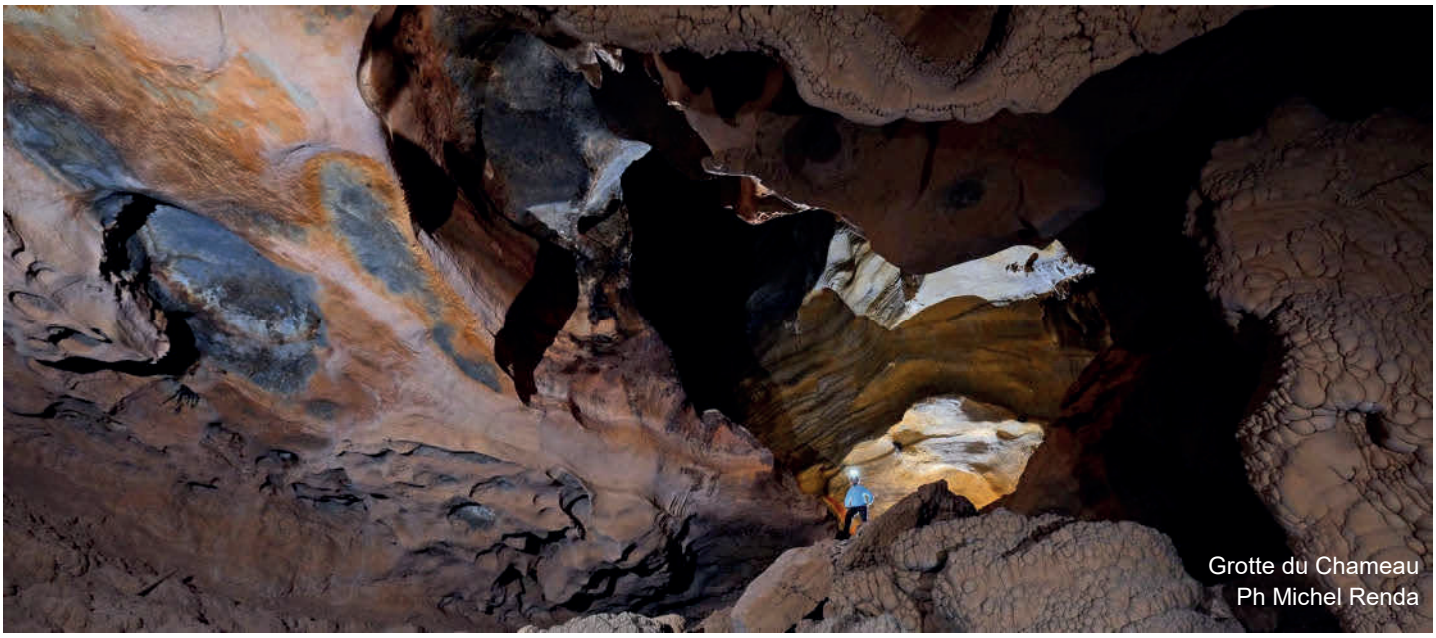
- Loi n° 22-80 relative à la conservation des monuments historiques et des sites, des inscriptions, des objets d'art et d'antiquité promulguée par le dahir n° 1-80-341 du 17 safar 1401 (25 Décembre 1980) (B.O. 18 février 1981).
- Loi n° 22-80 relative à la conservation des monuments historiques et des sites, des inscriptions, des objets d'art et d'antiquité promulguée par le dahir n° 1- 80-341 du 17 safar 1401 (25 Décembre 1980) (B.O. 18 février 1981).

•Dahir n° 1-16-113 du 6 kaada 1437 (10 aout 2016) portant promulgation de la loi n° 36-15 relative à l'eau Loi 22-07 re-

lative aux aires protégées

However, it should be noted that the Minister of Culture, Youth and Sports has already inventoried 107 caves with cultural heritage value. Included in this list, some that are registered and others that are classified as national cultural heritage, thereby receiving protection at a national level.

The importance of caves as significant natural and cultural legacy, lead the Moroccan government to propose in 2011 the draft law 52.13 included caves as immovable cultural heritage which will play a crucial role in recognizing caves as an important component of natural and cultural heritage once it's adopted.



Grotte du Chameau
Ph Michel Renda

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Ain D'Anou
Ph. Ayoub Nehili

# PALESTINE

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[1]Palestine Caving Club

Ph. Worood Sharabati

## GENERAL INFO

Palestine is located on the western side of the Great Rift Valley (Asian-African Rift). This makes it a region with a distinct geological structure. because of its location on the Rift, it leads to the diversity of its topographical and rocky layers. As a result of this active geological situation, most of the Palestinian areas are covered by limestone rocks, which, over time, have been subjected to torsion and cracking since millions of years ago. In addition, its situation made its conducive environment to the formation of many natural caves in its various regions. Despite of the geographical areas of Palestine, there are thousands of caves that were formed by natural factors or were built by man thousands of years ago. Most of the caves in Palestine are associated with the religions and many ancient civilizations that inhabited in Palestine and there are many legends and tales about them. Over the years, the Palestinians have been exploring caves in nearby areas, but the term (Speleo and Caving ) was not known until 2016, when a group of Palestinians established an initiative called the Palestine Caving Club that worked to spread these terms (Speleo and Caving) and explore the caves around them. Despite this, many caves in Palestine are still not registered because they are neglected and lack of awareness about their importance and necessity so the numbers that will be covered include the West Bank Area only

## NUMBER OF REGISTERED CAVES: NO DATA

**Most important caves**

| Name | Length (m) |
|---|---|
| Kharitun | 4,200 |
| Airak Alnuesan | 2,000 |
| Al'Janih Cave | 900 |
| Tur Al'safa Cave | ~500 |
| Kilzon | ~500 |

## ARTIFICIAL CAVES: ~1000

NUMBER OF SPELEOLOGISTS: NO DATA

NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 1


# SLOVENIA

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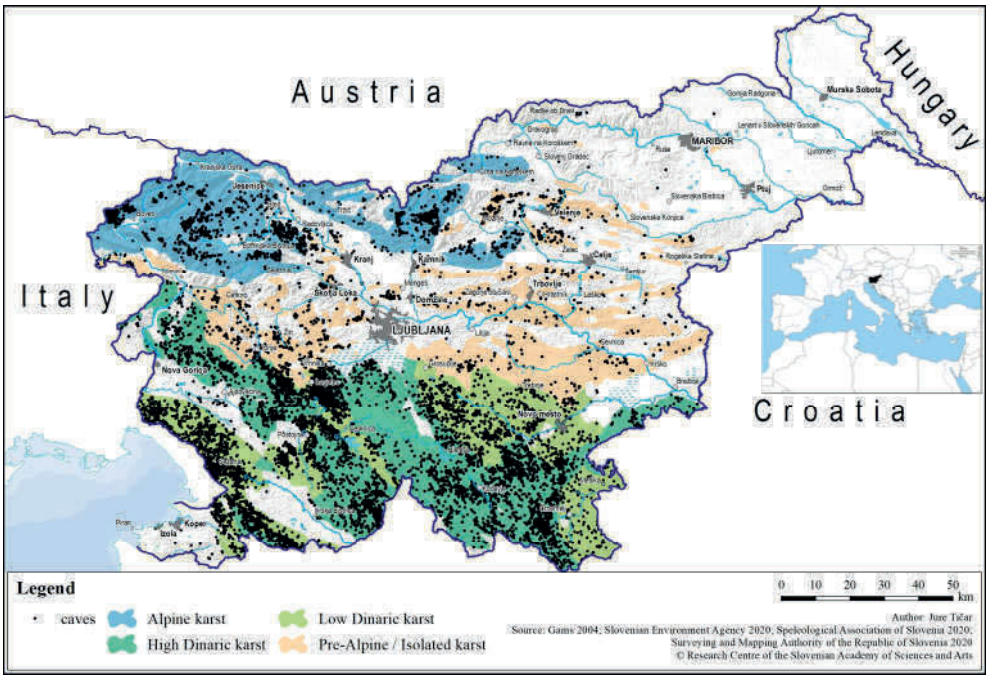
Cave 1 in Kanjaduce
Ph. Miha Staut

## GENERAL INFO

Slovenia is acknowledged as the cradle of karst and cave exploration. About 47% of the country's surface is occupied by carbonate rocks, with the prevalence of Mesozoic limestones and dolomites. Karst aquifers are crucial for water supply in Slovenia, providing more than 43% of drinking water. Among other distinct karst features, such as dolines, poljes, collapse dolines, karst plateaus, blind valleys, pocket valleys etc. numerous caves have been discovered in centuries of karst exploration. In fact, 14,196 karst caves have been registered up to date.




Karst in Slovenia divides into three types, such as 1) Alpine karst, 2) Dinaric karst and 3) Pre-Alpine or Isolated karst.

Mount Kanin
Ph. Jure Tičar

The Alpine karst comprises the mountainous areas of the Julian and Kamnik-Savinja Alps and the Karavanke Mountains in the northern and northwestern part of Slovenia. It has formed in limestones and dolomites, with the main faults following an east-west direction. Alpine karst has been affected by glaciation. Thus, glaciokarst features prevail on the

surface, while karst plateaus reveal numerous entrances to deep shafts. In Slovenia seven shafts deeper than 1,000 m have been discovered, Čehi 2 with 1,505 m being the deepest. Kanin and Rombon Mountain with other Alpine karst areas provide the potential for even deeper shafts.

The Dinaric karst in the southern part of Slovenia divides into 1) high Dinaric karst, which mainly includes high karst plateaus (for example Trnovski gozd, Javorniki, Hrušica and Snežnik Mountains), and 2) low Dinaric karst, which mainly includes low karst plateaus and plains (for example Kras Plateau and Bela Krajina). The Dinaric karst was formed in various carbonate rocks of predominantly Mesozoic age, with characteristic faults in the northwest-southeast direction. Here, the most distinct caves and cave systems formed, such as Postojna Cave System, Škocjan Caves (UNESCO), Predjama Cave System etc.

The Pre-Alpine or Isolated karst has formed in central Slovenia between the Alps and the Dinaric karst, where there are areas of smaller carbonate outcrops. Smaller caves are characteristic for this type of karst with Huda Luknja Cave System (2,8 km) and Cave Pekel (1,5 km) being the longest.

## Number of registered caves: 14169

| Longest caves | |
|---|---|
| **Name** | **Length (m)** |
| Migovec Cave System | 43,000 |
| Postojna Cave System | 24,120 |
| Kačna jama | 20,200 |
| Črnelsko brezno Cave System | 20,066 |
| Predjama Cave System | 16,755 |

Skednena Cave
Ph. Peter Gedei

| Deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| Čehi 2 Shaft | -1,505 |
| Črnelsko brezno Cave System | -1,393 |
| Renejevo brezno Shaft | -1,322 |
| Mala Boka Cave System | -1,319 |
| Vandima Shaft | -1,182 |

## ARTIFICIAL CAVES TOTAL: 2000 APPROX.

**Brief state of the art in artificial speleology**

In addition to its natural diversity, which depends on the interconnectedness of Dinaric Mountains, Alps, Mediterranean Sea and Pannonian Basin, Slovenia lies in the conglomerate of the cultural diversity of Middle Europe. This is also expressed in the needs of the population to use natural resources and defend their territories in times of conflict. Although there is no existing Register of Artificial Caves, underground man-made elements are common and also recognized in tourism.

**Bunkers** are the most common man-made element in the landscape. In the past, people sought shelter in caves and other natural elements, although World War 1 changed the picture. Along the western borders of Slovenia, the Isonzo Frontline was equipped with hundreds of forts, channels, tunnels, bunkers, etc., basically fortifying the mountains and plateaus. Bunkers and tunnels provided protection on the front line despite the difficult conditions. In the treeless landscape of Karst Plateau they were also the only way to get cover against enemy fire. Between WW1 and WW2, the Treaty of Rapallo was signed between the Kingdom of Italy and the Kingdom of Serbs, Croats and Slovenes, which led to further fortifications on the frontline. They also used other natural elements to fortify their positions, such as Unška koliševka Col-

Suhadolca Cave at Cerknica Polje
Ph. Matej Zalokar

lapsed Doline near Planina Polje in SW Slovenia. During WW2, numerous bunkers were built during the Axis occupation. After WW2, Yugoslavian Army built and used many bunkers around military installations and also built some secret military bunkers to facilitate the political regime in times of possible war.

**Hydrological work** was common in the second half of the 19th century and later, especially in connection with the regulation of flooding on karst poljes and ponors. It was believed that man could control flooding by widening passages, building tunnels, and placing rails on ponors to increase runoff. Such regulations and underground works can be well observed on the Planina Polje, Cerknica Polje, Lož Polje, Radensko Polje etc. One of the interesting elements are the so-called Putick's Wells in the northern part of Planina Polje.

**The tunnels** facilitate the crossing of the mountainous and hilly landscape of Slovenia and were built for both railways and roads. During the construction of the railway network in the 19th century, connecting Vienna and Trieste, many short tunnels were built, especially in SW Slovenia. However, the longest railway and highway tunnels are built under the Karawanke Mountains in NW Slovenia. Some of the newest tunnels were built during the construction of Slovenian highways, while many more are being built during the construction of the Divača - Koper railway in SW Slovenia.

**Mining** has a long tradition in Slovenian culture. In fact, the mercury mine in Idrija was put into operation as early as the 15th century, making it one of the oldest mines in Europe. Over centuries, more than 700 km of tunnels have been dug. Another old mine is located near the town of Mežica in NW Slovenia, where digging for lead and zinc began in the 17th century, creating about 800 km of underground passages. One of the most recent mines was dug near Žirovski vrh in NW Slovenia, where uranium ore was discovered. Other smaller mines yielded ores such as manganese, iron, anthracite, copper, antimony, molybdenum and baryte. Important coal mines were established in the towns of Trbovlje, Zagorje and Hrastnik in Central Slovenia, where lignite was mined from the 18th to the end of the 20th century. The largest operating mine for lignite is located in the town of Velenje, where it facilitates the Šoštanj Thermoelectric Plant. Due to intensive mining, the area above the mine subsided and three lakes formed on the surface. Most of the mines in Slovenia are closed today.

The abundance of various building stones led to the establishment of several quarries. Some of the quarries were also exploited underground. The most famous cases of such quarries are in Lipica and Debela Griža on Karst Plateau (SW Slovenia) and in Hotavlje (Central Slovenia). One of the special man-made underground features typical of Eastern Slovenia is called a "repnica". This is an underground chamber dug into the quartz sands and traditionally used for storing vegetables. Nowadays these chambers are used and dug for wine storage and facilitate the tourist offer.

Cave 1 in Kanjaduce with Reka River
Ph. Peter Gedei

## NATIONAL CAVING ORGANIZATION:

Speleological Association of Slovenia https://www.jamarska-zveza.si/

## NUMBER OF SPELEOLOGISTS: APPROXIMATELY 1000

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: APPROXIMATELY 50

## NATIONAL MAGAZINE AND MAIN SPELEOLOGICAL PUBLICATION:

“Jamar” https://www.jamarska-zveza.si/index.php/strokovne-sluzbe/ss-knjiznica/ss-k-slo-revije/jamar

“Naše jame” https://www.jamarska-zveza.si/index.php/strokovne-sluzbe/ss-knjiznica/ss-k-slo-revije/nase-jame

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST:

Speleological Association of Slovenia https://www.jamarska-zveza.si/

Karst Research Institute ZRC SAZU https://izrk.zrc-sazu.si/en/predstavitev#v

Speleobiological Group, Chair of Zoology, Department of Biology, Biotechnical Faculty, University of Ljubljana http://arhiv.bf.uni-lj.si/en/biology/department/chairs/

Kačna Cave
Ph. Miha Staut

## BIOSPELEOLOGY

Slovenia is situated at the extreme northwestern end of the Dinaric region, which is by far the richest in subterranean fauna in the world when compared with other regions of subcontinental size. The richness means about 517 recorded species of stygobionts and 783 species of troglobionts in the Western Balkans; in Slovenia there are 207 and 166 such species, respectively. Among the approximately 207 stygobiont taxa in Slovenia, there are 120 endemic taxa. *Crustaceans* predominate in aquatic habitats, and *Coleopterans* in terrestrial habitats. The region is also rich in *Gastropoda*, which are rather rare elsewhere. In addition, stygobiotic representatives of the cnidarians, freshwater sponges, freshwater tubeworms and clams are found only here. The reasons for the comparatively high diversity could be the absence of competitors, high speciation rates due to spatial partitioning, ecological partitioning in co-occurrences, favourable con-

stant temperature and a turbulent geological history.

Speleobiological research began here as early as the 17th century. Janez Vajkard Valvasor was the first scientist to describe the cave olm (*Proteus anguinus*) in his famous work The Glory of the Duchy of Carniola, thus arousing interest in the study of subterranean fauna. As such, *Proteus anguinus* later became commonly distributed among European scientists and played an important role in the emerging theories of evolution. After Luka Čeč's discoveries of new passages in Postojna Cave in 1818, a new cave species was found. It took until 1832 when *Leptodirus hochenwartii* was described as the first invertebrate cave animal by Ferdinand Jožef Schmidt. Another important discovery was made Postojna Cave by Emil Adolf Rossmässler, who described the first cave mollusk *Zospeum spelaeum* in 1839. Among the most recent discoveries, the karstologist Andrej Mihevc discovered an unusual dark pigmented olm in 1986 in Bela Krajina. It was later taxonomically described as *Proteus anguinus parkelj* and occurs only in a small area of about 100 km$^2$.

To date, 31 bat species have been recorded in Slovenia, one of which is presumed extinct, so that the number of species occurring in Slovenia is currently 30. The species living in our area are divided into four families: horseshoe bats (*Rhinolophidae*), simple-nosed bats (*Vespertilonidae*), long-winged bats (*Miniopteridae*) and free-tailed bats (*Molossidae*).

Proteus anguinus
Ph. Leopold Bregar

## LEGAL STATUS OF CAVES AND PROTECTION RULES

The first attempts to secure karst caves in Slovenia date back to the beginning of the 20th century, when Slovenian Nature Conservation Program was introduced. In the famous part of the Spomenica Act, prepared for Slovenia by the then Department for Nature Protection and Natural Monuments at Museum Association, there are several references to cave fauna and flora, securing entrances to important caves, and controlling and managing parks and caves.

Conservation measures were also triggered by the destruction and looting of speleothems for resale. In 1922, the Kingdom of Serbs, Croats and Slovenes enacted the "Act on the Protection of Rare or Typical Plants and Plants Important for Science and on the Protection of Caves in Provincial Administration for Slovenia," which in its Article 1 prohibited only hunting, killing and resale of certain cave animals and in Article 6 stated that "natural caves (caves) are under the supervision of the Provincial Administration for Slovenia, Forestry Department, and may be preserved and used only in a manner approved by the supervisory authority after consultation with the Museum Society for Slovenia." Karst caves had little protection in Slovenia in the 20th century through various laws such as the Nature Protection Act and the Natural and Cultural Heritage Act, or the protection of protected areas such as the Triglav National Park Act, but a more statutory and legally defined protection of karst caves only began with the Underground Caves Protection Act in 2004. The law regulates "the protection and use of underground caves, protection regimes, protective measures and other rules of conduct, including the restoration of underground caves that are polluted or damaged" and defines caves as natural values of national importance and natural public property and claims state ownership over them.

The protection of caves from pollution is also influenced by other laws. Article 5 of the Constitution of the Republic of Slovenia states that the state "shall provide for the preservation of natural resources and cultural heritage and create opportunities for the harmonious civilizational and cultural development of Slovenia", and Article 70 states that "the law shall determine the conditions for the use of natural resources", and in 70a that "everyone has the right to drinking water", in Article 72 that "everyone has the right to a healthy living environment in accordance with the law", and in Article 73 that

"everyone is obliged by law to protect natural sights and rarities as well as cultural monuments". The protection of caves from pollution is also indirectly regulated by the Law on Health Care and the Health Insurance, the Law on Protection from Natural and Other Disasters (1994), the Nature Protection Law, the Water Law and the Rules on Red List of Endangered Plant and Animal Species. Environmental Protection Act and the Rules on the Criteria for Establishing a Water Protection Area and Waste Decree. The activities of the state are also determined by strategic documents such as the Strategy for the Conservation of Biodiversity of Slovenia, the proposal of National Environmental Protection Program 2030, the Critical Infrastructure Act and the Decision on National Security Strategy of the Republic of Slovenia. However, the non-implementation of legislation and the lack of integration of various legal measures, such as Article 12 of the Underground Caves Protection Act, which requires monitoring of caves, leads to numerous discrepancies in the assessment of the extent of cave pollution in Slovenia.

Golokratna Cave
Ph. Peter Gedei

## ESSENTIAL COUNTRY BIBLIOGRAPHY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# SPAIN

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**Collaborators: José Maria Calaforra, Toni Pérez Fernández, Policarp Garay**

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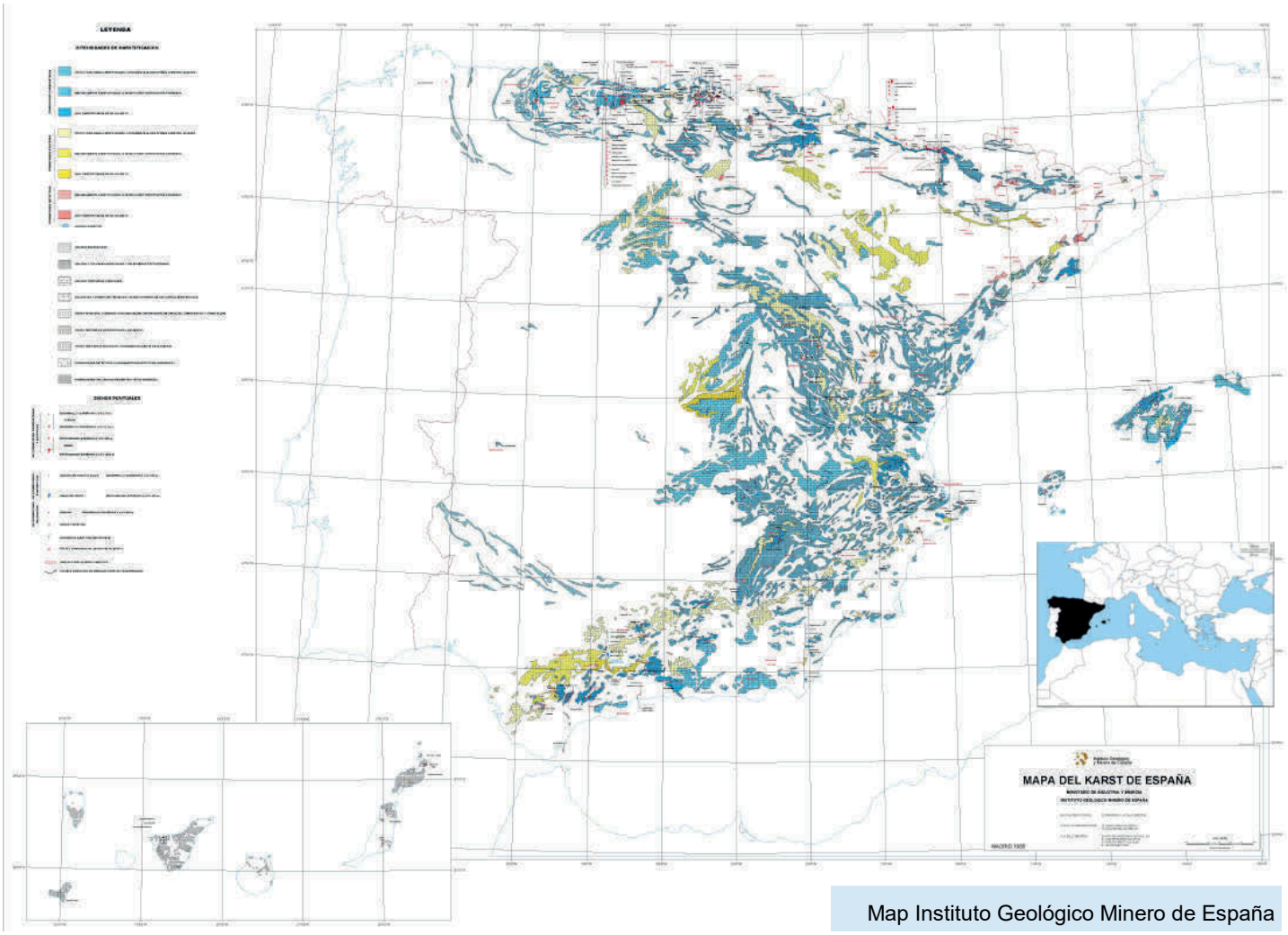
Sima del Campillo (Valencia-Spain)
Ph. Victor Ferrer

## GENERAL INFO

Spain is one of the countries with the largest karstified area in Europe. The extension of karstifiable carbonate rocks exceeds 100,000 km$^2$, almost 30% of the territory. The ages of these rocks range from the Paleozoic (Cantabrian Mountains, Asturias, Picos de Europa and León) to materials in Mesozoic basins such as the Ebro or the Duero. As for coastal cavities, the greatest development is in the Balearic Islands. Also noteworthy is the significant presence of gypsiferous rocks, essentially of Messinian or Triassic age, outcrops mainly in the Betic Cordillera and intramountain depressions. Evaporite outcrops in Spain exceed 35,000 km$^2$, around 7% of the surface. It should also be noted the presence of important cavities in salts, conglomerates and volcanic materials. In total, it is estimated that approximately 65,000 cavities are inventoried in Spain.




Map Instituto Geológico Minero de España

## KARST AREAS

Possibly, the best-known karst area in Spain is the Cantabrian Mountains and specifically Picos de Europa. In these massifs, from Asturias to the Basque Country, several cavities are located above 1,000 m in depth and developments greater than 100 km. In the Cantabrian sector, “historical” cavities stand out from the speleological point of view such as Cueto-Coventosa (- 829 m, 34.2 km), Tonio-Cayuela (- 527 m, 17 km) or Tibia-Fresca (- 507 m, 25.3 km) . Currently, the explorations carried out in these Cantabrian massifs have given rise to cavity connections forming networks that exceed 100 km such as El Alto Tejuelo (173 km), El Gándara (117 km) or El Mortillano (145 km). The Burgos area is also home to the Ojo Guareña system with 110 km. La Cordillera Pirenaica alberga también importantísimas manifestaciones kársticas en los macizos de Larra (Sima BU-56 o el Sistema de la Piedra San Martín entre España y Francia), la Sierra de Tendeñera con el Sistema de Arañonera (- 1.349 m, 45.2 km) or the Escuaín massif with the great integral Sima B15 up to the Escuaín-B1 upwelling (1,151 m, 38 km).

From the Pyrenees to the Mediterranean, the great variability of karst in the Catalan Coastal Chain stands out. In this

sector it is necessary to highlight the great density of cavities of the Garraf Massif (Avenc del Esquerrá - 298 m, Avenc de la Ferla - 180 m) where much of the speleology in Spain was forged.

Further south, in the foothills of the Iberian Mountain Range, the Cova de l'Autopista stands out in the province of Valencia (4.5 km), labyrinth of hypogenic origin.

Cova des Pas de Vallgornera (Mallorca-Spain)
Ph. Manuel Tremiño

Already entered the Betic domain, the Balearic Islands constitute one of the most exceptional examples of coastal karst on a world scale. Cavities such as Pas de Vallgornera with more than 80 surveyed km, a good part of them underwater, have been sampled to determine the variations in the level of the Mediterranean Sea by means of epiphatic speleothems.

The lithological variability of the Betic Cordillera, outcropping in the south and southeast of Spain, is another of the exceptional karst areas. The Sierra de Grazalema and Líbar stand out with emblematic cavities such as the Hundidero-Gato System (10.6 km) and the Sima de Villaluenga (4.7 km). The neighboring Sierra de las Nieves was the germ of vertical caving in Spain with the exploration of Sima GESM (18.5 km, - 1,059 m) to which new karst complexes of tens of kilometers of development and hundreds of meters deep that approach each other and are currently under active exploration (Sima del Aire 14.9 km, - 753 m, Sima Prestá - 803 m). Between Malaga and Cádiz, in nearby mountain foothills, the Motillas-Ramblazo Complex (9,133 m) is located, exceptional cavities due to its varied geomorphology and complex are genesis that reach almost 10 km of galleries.

In the Betic sector of southeastern Spain, the hypothermal system of the Cueva del Agua (Cartagena) stands out, as an emblem of extreme underwater explorations, with more than 5 km of surveyed galleries.

Also in the Murcia region, very unique hypogenic systems from the speleogenetic point of view have been recently explored, such as the Sima de la Higuera in Pliego (5,500 m) with speleothems unique in the world such as double cones or rediscovered systems from the point of view speleogenetic such as the Cueva del Puerto and the Sima del Pulpo with about 5 km of hypogenic development each. In Albacete, the Cueva de los Chorros System stands out, an important resurgence of the Calar del Mundo river with 35 km of development.

## CAVES IN OTHER LITHOLOGIES

Spain is home to a large number of cavities and outcrops of non-carbonated materials. The Sorbas gypsum karst stands

Pulpí Geode (Almería-Spain)
Ph. Victor Ferrer

out, developed in an intramontane evaporitic basin of the Messinian. In just 12 km$^2$, hundreds of cavities have been inventoried, some of them kilometers long, such as the Cueva del Agua (9,050 m), the largest gypsum cave in Spain. In the Triassic gypsum, also Betic, the Sumidor Tunnel (Vallada, Valencia) stands out, which was for a long time the largest unevenness in plaster in the world (- 210 m) and the Cueva del Yeso de Baena (2.7 km) of origin hypogenic.

The rock salt cavities are also a point and apart to be noted, especially the outcrops of the diapir of Cardona, La Montaña de Sal (Barcelona) where caves such as El Forat Micó or Els Meandres de Sal (4.3 km, 187 m unevenness).

Also in Catalonia, singular cavities are located in conglomerates with some of the most developed and deep caves in the

Forat Micó (Barcelona-Spain)
Ph. Victor Ferrer.

world in these materials such as Cova Cuberes in the province of Lleida (13 km, - 328 m) or the Cova de l'Espluga in Tarragona (3.6 km). In these materials, the Fuentemolinos cave in the province of Burgos with spectacular speleothems and phreatic conduits (4 km) also deserves special mention for its uniqueness.

Finally, it is worth mentioning the important lava ducts that have developed in almost all the islands of the Canary Islands archipelago, among which the Cueva del Viento de Tenerife (17 km) stands out with a very unique network of ducts and associated fauna.

Cueva de los Chorros (Albacete-Spain)
Ph. Victor Ferrer.

## MOST IMPORTANT SHOW CAVES

Almost 38 tourist caves are actively operating in Spain. Some of the best known for their uniqueness are.

The Cave of Wonders (Huelva) 2.1 km. One of the first cavities that were enabled for tourism in Spain (1914), it develops in the Cambrian marbles with an ancient speleo-genesis possibly linked to hydrogen sulfide. It stands out for its aragonite speleothems, some blue, that upholster the walls of some rooms.

Nerja Cave (Málaga) 4.8 km: discovered in 1959, it immediately enabled tourism to tour a large part of the great Cataclysm Hall, it develops in dolomitic marbles of the Sierra de Almijara and in its genesis the dissolution by mixed waters may have been of great importance given its proximity to the sea. Coves del Drac (Mallorca) 7.7 km; Coves de Sant Josep (Castellón) 3 km;  El Soplao (Cantabria) 23 km; Valporquero (León) 3,5 km.

## NUMBER OF REGİSTERED CAVES: 65000

**Most important longest caves**

| Name | Province | Length (m) | Depth (m) |
|---|---|---|---|
| Sistema del Alto Tejuelo | Cantabria | 173,000 | - 626 |
| Sistema del Mortillano | Cantabria | 145,000 | - 950 |
| Sistema del Gandara | Cantabria | 116,700 | - 814 |
| Ojo Guareña | Burgos | 110,000 | |
| Sistema del Hayal de Ponata | Araba | 90,000 | - 451 |
| Cova del Pas de Valgornera | Baleares | 80,000 | |

**Most important deepest caves**

| Name | Province | Depth (m) |
|---|---|---|
| Sistema Cuetu'l Cuevón - Saxífragas | Asturias | - 1,589 |
| Sistema de la sima de la Cornisa - Torca Magali | Asturias | - 1,507 |
| Sistema'l Trave | Asturias | - 1,441 |
| Sistema de la Piedra de San Martin - Partages | Zuberoa (F) Nafarroa (E) | - 1,410 |
| Sistema Arañonera | Huesca | - 1,349 |

## MARINE CAVES: 138

In Spain there are many sea caves. Volcanic caves in the Canary Islands, granite in Galicia and calcareous in the Cantabrian and Mediterranean area. Despite this, there is no complete catalog, so this figure is much lower than reality.

## ARTIFICIAL CAVES: 2000

There are many mines and underground aqueducts. Some have been conditioned for the tourist view, others that are abandoned can be visited.

Avenc dels Pouetons de les Agulles (Barcelona-Spain)
Ph. Victor Ferrer

## REFERENCE RESEARCH ORGANIZATIONS FOR CAVES AND KARST

- Spanish Society of Speleology and Karst Sciences (SEDECK). The purpose of the Spanish Society of Speleology and Karst Sciences is to promote and disseminate the sciences of Speleology and Karst in general, to promote scientific studies related to the conservation of cavities and their natural contents and to facilitate scientific communication among interested persons in the study of karst and maintain an effective dialogue channel with the administrations and entities dedicated to the management of this environment. www.sedeck.org
- The Catalan Institute of Speleology and Karst Sciences (ICEK) Barcelona. Promotion of Scientific Speleology and the Study of the Karst. http://icekinstitut.blogspot.com/
- Some speleological studies, which focus mainly on mines, are carried out by the Geological and Mining Institute of Spain, which has a long tradition in the study of karst and Spanish cavities. The first catalog of caves in Spain was published by the IGME in the 19th century; at the end of the 20th century, it edited the Karst Map of Spain, at a scale of 1:1,000,000.

## NUMBER OF SPELEOLOGİSTS: 9400

## NUMBER OF SPELEOLOGİCAL GROUPS AND ORGANİZATİONS: 346

## NATIONAL CAVING ORGANIZATION:

- CEC. Confederación de Espeleología y Cañones

## NATIONAL MAGAZINE:

- Subterránea

## MAIN SPELEOLOGICAL PUBLICATIONS:

- Mediterranean Caves. http://mediterraneancaves.esy.es
- Exploracions Sotaterra
- Lápiaz
- Furada
- Boletin Museo de la Espeleologia
- Karaitza
- Endins
- Serie Granada Subterránea
- Andalucía Subterránea
- Calar
- Gota a Gota
- Kaite
- S.E.D.E.C.K.
- Cubia
- Subterránea
- Revista del SIS de Terrassa
- Espeleocat

*Valenciolenda fadaforesta*
Ph. Sergio Montagud

## BIOSPELOLOGY

At the beginning of the 19th century, Spain was a center for studies, sampling and visits by European entomologists, botanists and naturalists, especially Germans, Belgians and French. During these visits, they tried to catalog, above all, the animals that lived in them, from bats to invertebrates. Spanish entomologists and naturalists also joined in the second half of the 19th century. But it is not until the appearance of *Biospelologica* and the renowned entomologists René Jeannel and Émil Ratcovizta when the real studies of the underground biology of the Spanish territory begin.

There are many works that have been carried out in the Iberian Peninsula, in the Canary Islands and in the Balearic Islands in all this time, having a multitude of species of great interest, with adaptive characters to the subterranean environment, spectacular endemisms and Spanish biospeleologists of recognized prestige international, being at present a country of reference around the study of underground biology.

In particular, around the study of bats, it should be noted that in the Spanish territory there are more than thirty species of bats cataloged, most of them included in the Red Book of Vertebrates of Spain, and specifically they have more cave-dwelling habits, of half of them, being almost all classified as Vulnerable or Endangered. The most common genera to be found in Spanish cavities at some time of the year are *Myotis Kaup*, 1829, *Rhynolophus Lacepède*, 1799, *Miniopterus Bonaparte*, 1837 and *Pipistrellus Kaup*, 1829. For more information we leave two links to Spanish research centers:

- **SECEMU**: http://secemu.org/
- **Museum of Natural Sciences of Granollers**: http://quiropteros.org

Regarding the flora of cave-dwelling environments, especially in the first meters of the Spanish caves and chasms, mention the existence of the only hybrid fish of the world with adaptations to the underground environment and the second fish existing in Europe in cavities, which It is located in Jaén, called *Squalius alburnoides* (Steindachner, 1866). Numerous works have been carried out, especially on ferns, mosses and other species of interest that need special habitats, such as entrances cavities. Some conservation programs for this flora have been carried out in specific caves, as is the case in several cavities in the Valencian Community, where there is eminently threatened flora, where the cavities have incalculable value and potential for their habitat.

Around the invertebrate fauna, a multitude of species of various classes, orders and different families are known, whether microscopic species or macroinvertebrates. For example, the study of cave nematofauna in the south of the peninsula or the malacofauna that inhabits caves throughout the Spanish territory, highlighting species of the genera

*Gollumjapyx smeagol*
Ph. Sergio Montagud

*Zospeum Bourguignat*, 1856 and *Oestophora Hesse*, 1907.

Regarding entomofauna and arachnofauna, Spain is one of the world's hot spots, due to its endemicity, diversity and troglomorphisms, not only in the terrestrial environment, but also with aquatic invertebrates. On the other hand, there are many studies and works in the Deep Subterranean Environment (caves, chasms and artificial cavities) and in the Superficial Subterranean Environment (fissures and microfractures of the bedrock), although we will focus mainly on the former.

Both in the peninsula and in the Canary and Balearic Islands, there are many examples of relict animals, endemic and with great troglomorphism, considered as living jewels in a world of total darkness. The wealth of the invertebrates of the Spanish subterranean environment is immense, but we will mention some species of interest: the aquatic crustaceans *Hispanobathynella catalanensis* (Serban, Coineau & Delamare Deboutteville, 1971), *Kensleylana briani (*Bruce & Herrando-Pérez, 2005), species of the genera *Bathynella Vejdovsky (*Serban & Leclerc, 1984), *Niphargus Schiödte*, 1849, *Pseudoniphargus Chevreux*, 1901 and *Proasellus Dudich*, 1925; the pseudoscorpions *Troglobisium racovitzai* (Ellingsen, 1912) and *Arcanobisium comasi (*Zaragoza, 2010) both endemic to the northwest of the peninsula; the araneids *Speleoharpactea levantina (*Ribera, 1982) from the Spanish Levant, *Dysdera sibyllina (*Arnedo, 2007) from the Canary Islands and various genera and species of the *Linyphiidae* family; palpigrades of the genus *Eukoenenia (*Börner, 1901) from various cavities of the peninsula and the Balearic Islands; the endemic Opiliones of the Canary Islands *Maiorerus randoi (*Rambla, 1993) and the endemic Opiliones of the Balearic Islands *Scotolemon balearicus (*Rambla, 1977); the Hemiptera *Valenciolenda fadafoesta (*Hoch & Sendra, 2021) endemic to Valencia caves and *Collartida tanausu (*Ribes, Oromí and Ribes, 1998) endemic to the Canary Islands; the recently described oniscid isopod *Baeticoniscus bullonorum (*Garcia, 2020) endemic to a cave in Malaga; the japíjido *Gollumjapyx smeagol (*Sendra & Ortuño, 2006) endemic to caves in the northwest of the peninsula; the diplopod myriapods *Cantabrosoma rogeri (*Mauriès, 1970) from caves in the north of the peninsula and the different species of the Julidae family; the Carabid beetles *Dalyat mirabilis* (Mateu, 2020) endemic to cavities of Almería, *Ildobates neboti* (Español, 1966) endemic to cavities of the north of Castellón, *Paraphaenops breuilianus* (Jeannel, 1916) of cavities of the northwest of the peninsula, *Henrotius jordai* (Reitter 1914) endemic to caves in the Balearic Islands, the two species of the genus (*Tinautius Mateu*, 1997) from cavities in Almería and Jaén and the recently described *Iberotrechodes spinosus* (Faille, Balart-García, Fresneda, Bourdeau & Ribera, 2021) endemic of caves in northern Spain; curculionids of the genera *Oromia* (Zarazaga, 1987 and Laparocerus Schoenherr, 1834) in cavities of the Canary Islands; and finally, the blatélid *Symploce microphthalma* (Izquierdo y Medina, 1992) endemic to the Canary Islands.

Francesc Español Coll

For the conservation of these invertebrates there is the Atlas and Red Book of Threatened Invertebrates of Spain (published in 2011 and although it is a recent edition, it is now obsolete in many of the species that are cited and others that must be added) in the that a total of 20 species cataloged in different categories and that have habitats in the subterranean environment are listed.

Featured links on Spanish underground biology:

- **Biología Subterránea: un mundo por descubrir:** https://bioespeleologia.blogspot.com/
- **BIOSP Association**: http://biosp.blogspot.com/

Francesc Español Coll. His scientific work focused on beetles, especially their taxonomy and the underlying biogeographic aspects: https://es.wikipedia.org/wiki/Francesc_Espa%C3%B1ol_Coll

## LEGAL STATUS OF CAVES AND PROTECTION RULES

The caves can be public or private property, depending on who is the owner of the land where they are located.

The main Spanish tourist caves are owned by local administrations (city councils) although some are private.

There are general norms of conservation or protection in those cases in which some form of protection is present (World Heritage, Assets of cultural interest, Natural Monuments ... for example). In Natural Parks and more strictly in National Parks, there are usually specific rules to regulate explorations and research work in caves. For example in the Picos de Europa, Monte Perdido in the Pyrenees or Sierra de las Nieves in Malaga.

In Catalonia there is a model of karst protection. Cavities declared "Area of Geological Interest of Catalonia" (EIGC), the highest distinction granted by the Generalitat of Catalonia to natural resources of great interest, object of protection.

In the Valencian community all caves are protected in general, under the article 16 of Law 11/1994, on Protected Natural Spaces of the Valencian Community. There is also Decree 65/2006 of the Consell, by which the regime of protection of the caves is developed and the Catalog of Caves of the Valencian Community is approved. Karst systems in general and caves in particular offer environmental values of special interest. On the one hand, of a geological nature, since there is a great geodiversity around these underground phenomena and they form an important part of a geological heritage that man must assume, respect and conserve. It is also worth highlighting the biological and ecological aspects, since caves constitute very interesting fragile ecosystems, characterized by an enormous specialization of the living organisms that make them up and by a surprising biodiversity adapted to conditions of total darkness and a high degree of humidity that are typical of this medium (text extracted from the decree).

The Association of Spanish Tourist Caves includes cavities open to the public from all corners of Spain where there is an underground heritage. The Association's missions are to preserve these caves and show them to visitors, thus making it easier for the general public to know and enjoy them.

Sima del Pozo (Murcia)
Ph. Victor Ferrer

Sala Bancobao
Ph. Victor Ferrer

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# SYRIA

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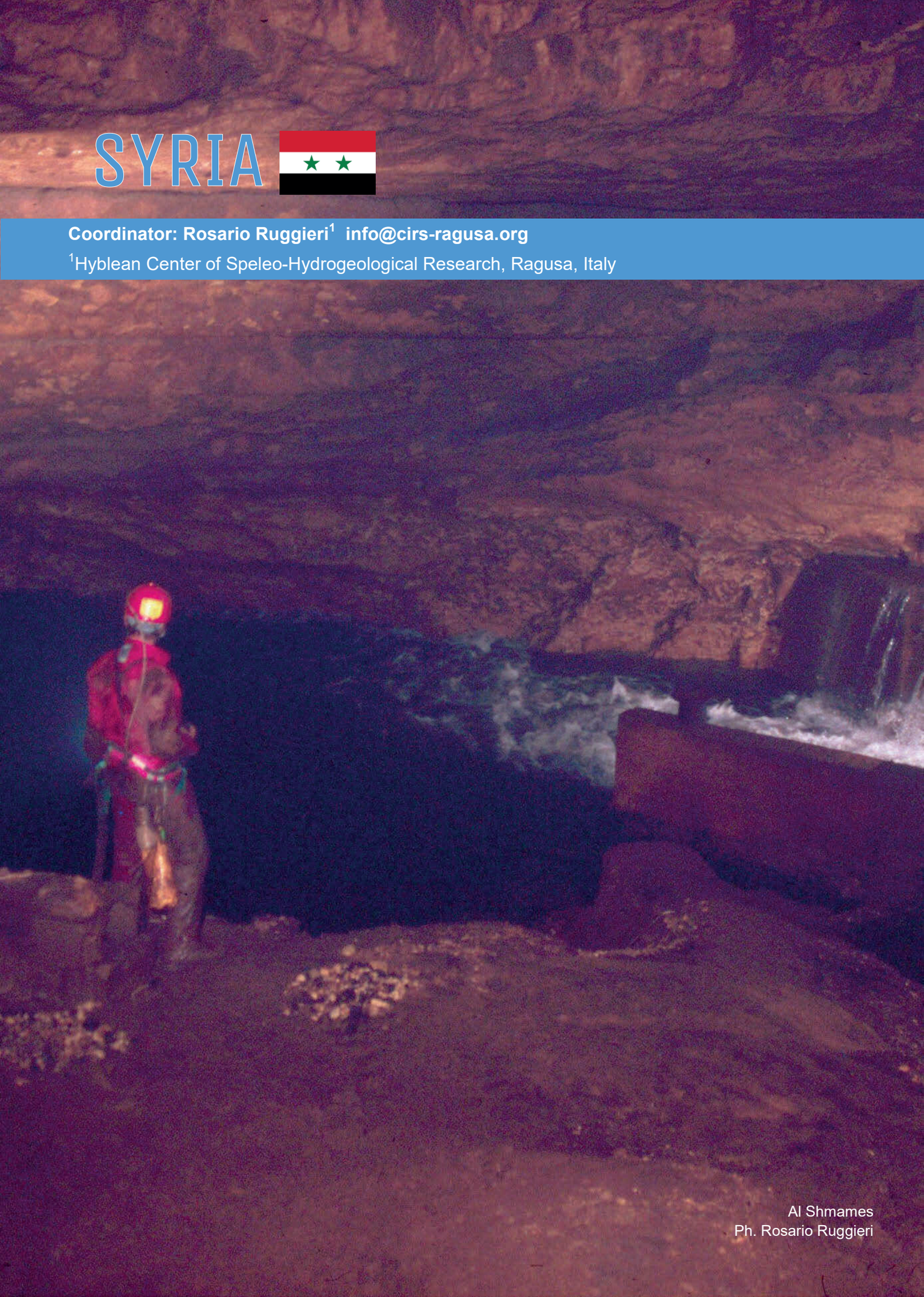

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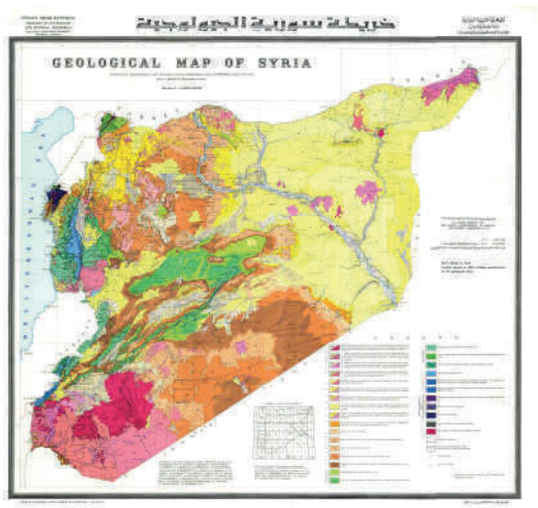
Ph. Rosario Ruggieri

## PHISICAL AND LITHOLOGIC NOTES




### Morpho-lithological note

In the country the following morphological areas can be distinguished, in relation to the climatic and orographic characteristics. The western sector is characterized by the large limestone chains of the Jurassic-Cretaceous age, which run for about 300 km parallel to the Mediterranean (Mt. Hermon, Antilibano, Jebel Ansairyia). To the east of the above mentioned chains (to the north with Turkey), a huge subarid limestone area with continental climatic features extends, while to the south of Palmyra the climate is desert with sedimentary outcrops of arenacean and clayey nature. Finally, in the north-east of the country, in the desert environment, the relief is characterized by plateaus with evaporitic outcrops of the Miocene, (Calandri, 1991).

### Karst-hydrogeological note

In Syria there are four lithological-stratigraphical successions which have evolved into karstic aquifers. They are the carbonate sediments of the Jurassic (1,000 to 2,400 metres), of the Middle Cretaceous (650 to 650 metres) and of the Tertiary (irregular distribution and thickness) as well as the highly-soluble evaporate beds of the marine-lagoonal Lower Fars (Middle Miocene). Post-Jurassic and post-Cretaceous emergences gave rise to paleokarst, while minor Miocene and Pliocene karsts are suspected. The main kartsification, however, is of Quaternary age and must be connected with Pluvials. Concerning the aquifers, there is an upper “Carapace zone” which is dry, a central “Open karst Aquifer Zone” and an underlying “Unkarstified Carbonate Floor Zone” which is also dry. The water in the aquifer zone is frequently under pressure and will rise into or above the Carapace zone (Burdon & Safadi, 1964).

**Most important longest caves**

| Name | Region | Length (m) |
|---|---|---|
| Cafer Megara | Al Raqqa area,Euphrates | 7,300 |
| Joiat cave | Tartous area | 2,600 |
| Pigeon Magara | Al Raqqa area,Euphrates | 860 |
| Grotta di Ratla | Area Al Raqqa | 500 |
| Nugaret Douaiet | Jebel Ansairyia | 400 |


Bet Ana cave
Ph Rosario Ruggieri


Cave Al Dawayeat
Ph. Rosario Ruggieri

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# TUNISIA

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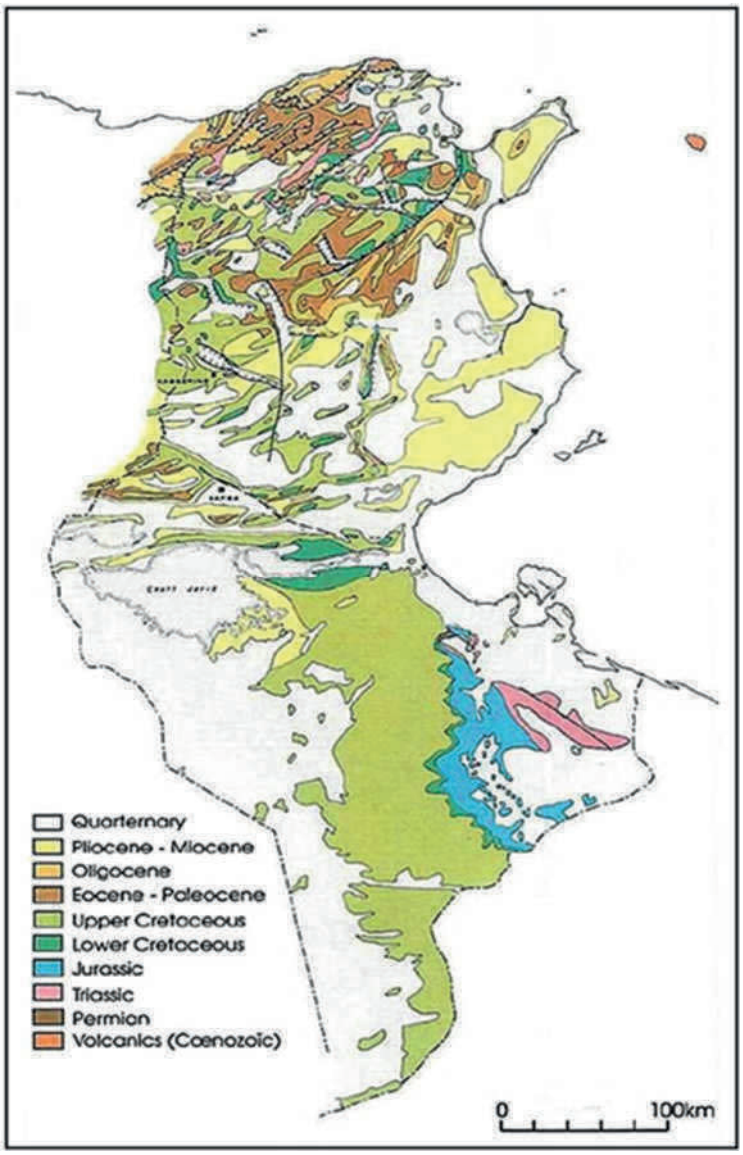
**Collaborators: Wassim Mahfoudh, Ghassen Abderrahim**
[1]Zaghouan Caving and Climbing Association

Ain D'hab cave
Ph. Phil Bence

## GENERAL INFO

Tunisia surface is of 163,610 km$^2$. The country, officially the Republic of Tunisia, has a population of approximately 11 million and is part of the Maghreb region of North Africa;

Tunisia has a shoreline 1,148 km, and a Mediterranean climate with mild rainy winters and dry summers with an average falls of 370.9 mm. Mount Ash-Sha'nabi (8.682862,35.206722 Dec Deg) is the highest mountain with an elevation of 1,544 m in the eastern Atlas Mountains, geoloagically it is a karst mountain dry and seared by erosion; composed of a sedimentary rock: caliche a hardened natural cement of calcium carbonate, that binds other constituents such as gravel, sand, clay, and silt. The Tunisian Dorsale is the northeastern extension of the Saharan Atlas Mountain range of Algeria, and the High Atlas Mountain range in Morocco. It consists of a series of northeast-trending limestone mountain ranges, which culminate at Kaf ash-Sha'nabi (Mt. Chambi: altitude 1,544 m ;) near the Algerian border. The Dorsale is bordered by high and low steppes (grassland and shrub plains), which decrease in altitude eastward toward the coastal plain along the Mediterranean coast.




Geological map of Tunisia (Mohamed Essghair Gaied) in Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures DOI 10.1007/978-94-007-3934-5_10016-1 # Springer Science+Business Media Dordrecht 2014

## KARST AREAS

Speleology in Tunisia is an activity that developed at the end of the 1970s. Tunisia has a geological platform that suites caving and has several sites (caves, pits, etc.) spread over the entire Tunisian territory. The first report on Tunisian caves dates from the 1880s. Édouard-Alfred Martel, was the first source of information on cave explorations, including on the Tunisian island of La Galite .

Karst areas are numerous but limited. Except the Jurassic limestone massifs of Zaghouan, Fkirine and Bent Saidane, important layers may be mentioned in Sarj and Bargou mountains. The two massifs of Djebel Serj and Djebel Bargou, belong to the folds of the Tunisian ridge. The entire framework of the massif is formed by land of Aptian age, of which the limestone reefs at the top constitute almost all of the outcrops. We find most of the Tunisian caves in the massifs of Djebel Serj and Djebel Zaghouan.

## NUMBER OF REGISTERED CAVES: 200

**Longest caves**

| Name | Length (m) |
|---|---|
| La Mine | 4,100 |
| Ain Dhab | 3,000 |
| Ghar Kriz | 1,130 |
| Damous Sbaa | 440 |
| Nefza | 310 |

| Deepest caves | |
|---|---|
| **Name** | **Depth (m)** |
| La Mine | -395 |
| 4 fous | -265 |
| DZ 9 | -150 |
| Ete 2000 | -110 |
| Mongass Lahmem | -100 |

La Mine cave
Ph. Meher Melaouhia

## ARTIFICIAL CAVES

In addition of natural caves, other artificial cavities are scattered all over Tunisia such as the Roman underground aqueducts, the Roman underground quarries, the cave dwellings in the south, the French and German military defensive lines, the Roman granaries, water cisterns.

## NUMBER OF SPELEOLOGISTS: 100

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 15

## BIOSPELEOLOGY

Tunisia has a rare documentation of biospeleologie. Nevertheless, an Inventory of cave dwelling chiropterans in Tunisia was made based on data from more than 15 known caves and mines that concluded the existing of 6 big families; Rhinolophidae, Vespertilionidae, Hipposideridae, Rhinopomatidae, Molossidae, Miniopteridae, that leads to 11 genders and 19 species of bats.

## LEGAL STATUS OF CAVES

There is no legal framework specific to the caves in Tunisia. The new mining code no. 2003-30 of 28 April 2003 states that the subsoil belongs to the public domain of the Tunisian state.

All cave visits require prior authorisation from the ministry in charge of the public domain where the cave is located (ministry of Agriculture if the cavity is in a national park, ministry of Defence if the cavity is in a military zone, etc.). Furthermore local police must be informed of the visit as well as the participants identities.

Ain Dhab cave
Ph. Robbie Shone

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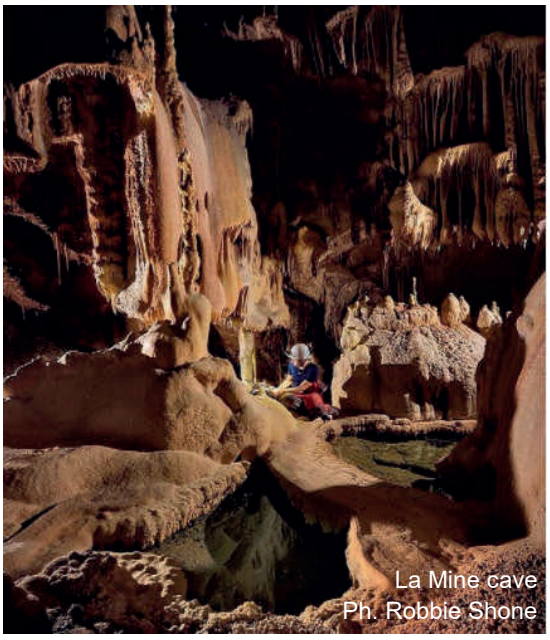
La Mine cave
Ph. Robbie Shone

# TURKEY

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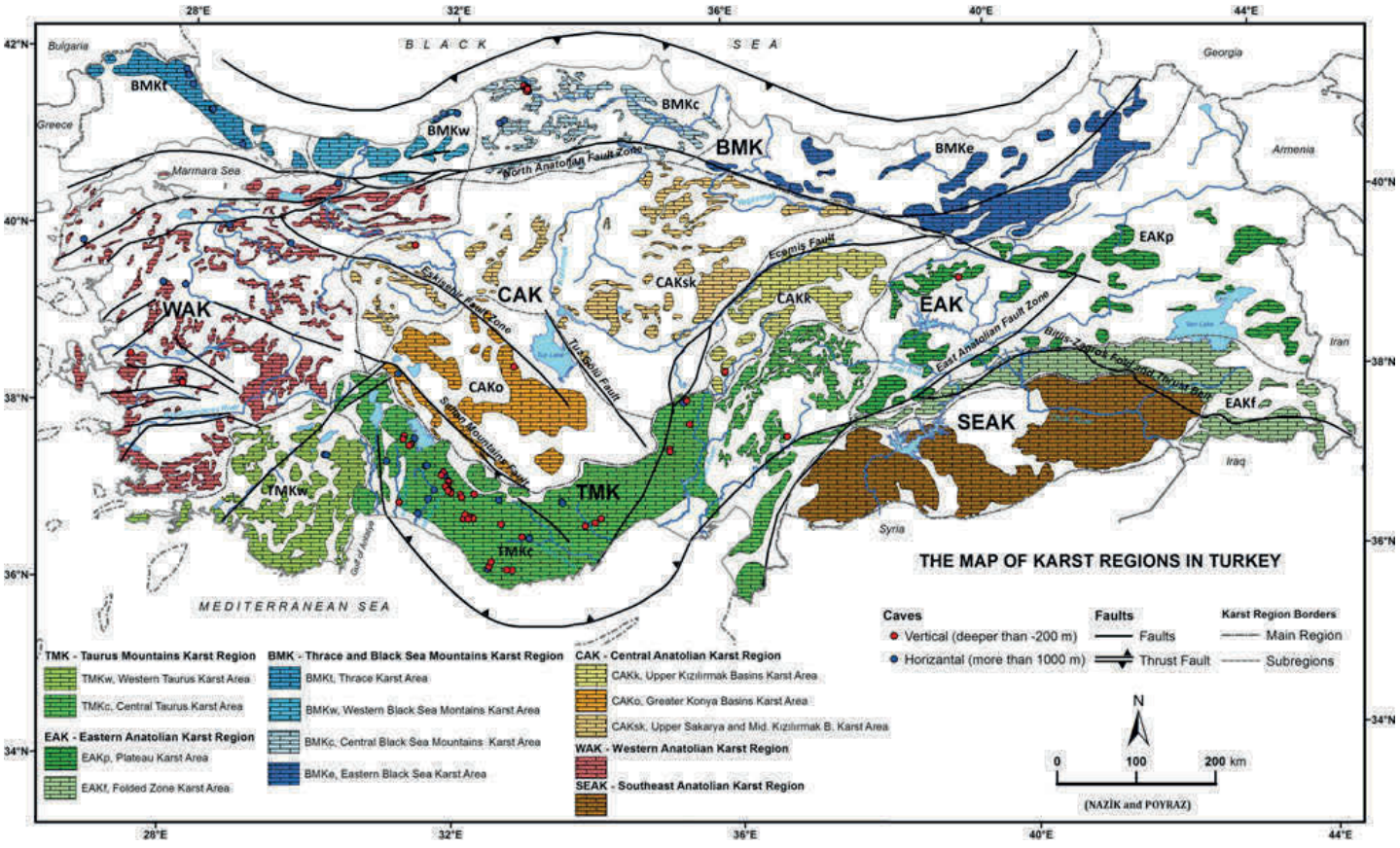
Çukurpınar Sinkhole
Ph. M. Albukrek

## KARST AREA

Approximately, 40% of Turkey's landmass consists of soluble rocks (limestone, dolomite and gypsum) highly suitable for karstification. While presenting different lithological composition, lithostratigraphic and structural characteristics, these rocks reach in some places up to 4,000 m in elevation. Tectonic movements since the middle Miocene have played, together with climate, a major role in the processes of karst development. Several factors intervene in the formation processes and history of the karstic landscapes of Turkey: structural dynamics (mainly extensional tectonics and block faulting) and its spatial distribution, relief rejuvenation responding to the combination of uplift intensity and sea-level changes and the stratigraphic/lithologic context. Resulting from the various combinations possible, there are large-scale differences in the evolution of the karstic landscape within short distances. Consequently, six karstic regions and eleven distinct sub-karstic areas can be identified on the basis of their different morphogenetic and morphometric characteristics.




The high diversity of Turkey's landscapes results from a complex geological history during which present landforms have been shaped by intense tectonics related to the collision between the African, Arabian and Eurasian plates since the mid-Miocene. To the north and to the south, the Turkish relief includes mountain ranges that plunge into the surrounding seas (Mediterranean, Aegean, Marmara, Black Sea) leaving only narrow coastal zones. Between both mountains the vast plateau of Central Anatolia extends. It rises gradually to the east, towards the Anatolian highlands. Several high volcanoes are present inland, among which is the Ararat (5,136 m) which is the highest summit of Turkey. The mean altitude of the country is quite high (1,100 m). The climate of the western part is mainly of Mediterranean type, with mild winters and hot and dry summers. The Anatolian Plateau which is surrounded by high mountains offers a more continental climate, dry, cold in winter and very warm in summer, while in the northern zone, close to the Black Sea, it is more humid. Lithology also explains the variability of the relief and the diversity of the karst zones. Soluble rocks concern 40% of Turkey's superficy and karsts are present on the whole country, from high mountain zones like Akdağ Mountain (3,016 m) to sea shores. The ages of the rocks vary from Palaeozoic to late Cenozoic. In some places the total thickness of the main carbonate series may overpass 1,500 m. Surface features are well developed in several zones like Taurus Mountains, Konya areas or Black Sea Mountains. Some specific forms like the Antalya tufas, the Pamukkale rimstones, the Taurus poljes and the Konya obruks are worldwide known. Karsts and cave studies started in

the 1960s with the work of Temuçin Aygen a geologist from Ankara University.The caves explored and researched in Turkey until now are predominantly centered in the Taurus Mountains, West Anatolia, and Western Black Sea regions. The number of caves in the Eastern Black Sea and Central Anatolian regions, which are not geomorphologically suitable for the formation of caves, is limited. On the contrary, the number of researches carried out for the caves in the southeastern region, outcropped with limestone on quite wide areas, is not sufficient.

## NUMBER OF REGISTERED CAVES

TAY Project Cave Inventory of Turkey (www.tayproject.org) carried out based on the published documents, includes 3,050 caves for the present.

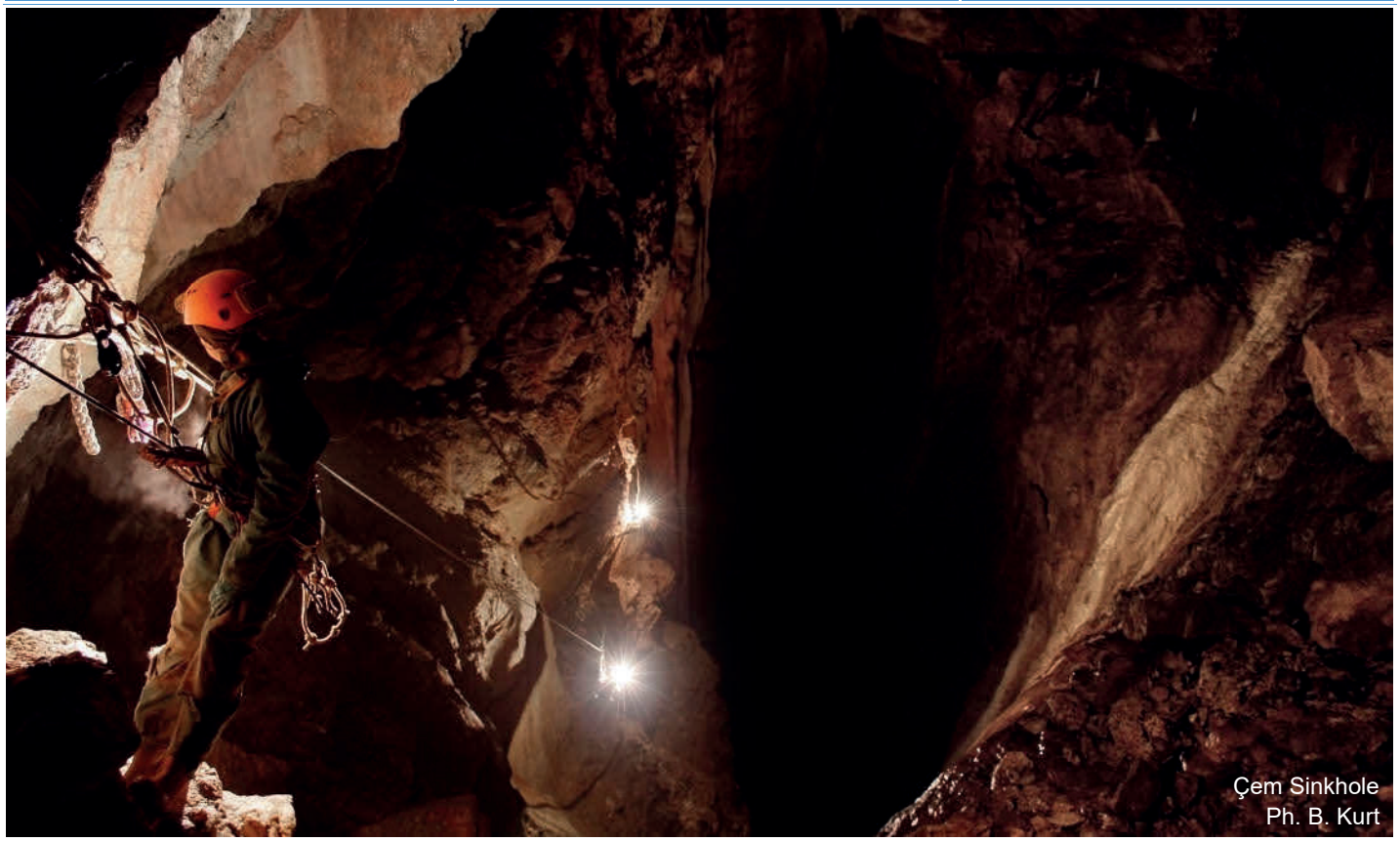
**Most important longest caves**

| Name | Province | Length (m) |
|---|---|---|
| Pınargözü Cave | Yenişarbademli, Isparta | 8,500 |
| Insuyu Cave | Burdur | 8,350 |
| Tilkiler Cave | Manavgat, Antalya | 6,818 |
| Kızılelma Cave | Zonguldak | 6,630 |
| Yaylacık – Inilti Pazarı System | Gündoğmuş, Antalya | 5,929 |
| Bulak Mencilis Cave | Karabük, Safranbolu | 5,250 |
| Altınbeşik Cave | Akseki, Ürünlü, Antalya | 5,119 |
| Ayvaini Cave | Ayvaköy, Bursa | 4,866 |
| Ikigöz Cave | Çatalca, Istanbul | 4,816 |
| Morca Sinkhole | Anamur, Içel | 4,068 |
| Yazören Cave | Yazören, Balıkesir | 3,554 |
| Çukurpınar Sinkhole | Anamur, Içel | 3,350 |
| Gökgöl Cave | Erçek, Zonguldak | 3,350 |
| Kuzgun Sinkhole | Niğde | 3,187 |
| Dupnisa Cave | Sarpdere, Kırklareli | 3,150 |
| Peynirlikönü Sinkhole | Anamur, Içel | 3,118 |
| Düdenağzı Sinkhole | Başyayla, Karaman | 2,528 |
| Susuz Cave | Seydişehir, Konya | 2,303 |
| Tınaztepe Caves | Seydişehir, Konya | 2,195 |
| Kızılin Cave | Burdur | 2,176 |
| Saçayağı Cave | Gazipaşa, Antalya | 2,125 |

Kocain Cave
Ph. B. Langford

**Most important deepest caves**

| Name | Province | Depth (m) |
|---|---|---|
| Peynirlikönü Sinkhole | Anamur, Içel | - 1,429 |
| Kuzgun Sinkhole | Niğde | -1 ,400 |
| Morca Sinkhole | Anamur, Içel | - 1,210 |
| Çukurpınar Sinkhole | Anamur, Içel | -1196 |
| Kuyukule Sinkhole | Dedegöl, Isparta | - 832 |
| Keş Sinkhole | Kahramanmaraş | - 728 |
| Subatağı Sinkhole | Yahyalı, Kayseri | - 643 |
| Sütlük Sinkhole | Pozantı, Adana | - 640 |
| Düdenağzı Sinkhole | Başyayla, Karaman | - 612 |
| Çem Sinkhole | Tomarza, Kayseri | - 605 |
| Yılanlıyurt Sinkhole | Aladağ | - 603 |
| Yaylacık – Inilti Pazarı System | Gündoğmuş, Antalya | - 595 |
| Kocadağ Sinkhole | Anasultan, Kütahya | - 458 |
| Pınargözü Cave | Yenişarbademli, Isparta | + 440 |
| Düdenyayla Sinkhole | Beyşehir, Konya | - 416 |
| Atlılar Sinkhole | Gözne, Içel | - 410 |
| Çamlıköy Sinkhole | Pozantı, Adana | - 379 |
| Macar Sinkhole | Gazipaşa, Antalya | - 356 |
| Bucakalan Sinkhole | Akseki, Antalya | - 345 |
| Ölü Köpek Sinkhole | Akseki, Cevizli, Antalya | -340 |
| Düdencik Sinkhole | Akseki, Cevizli, Antalya | -330 |



Çem Sinkhole
Ph. B. Kurt

## MARINE CAVES

A total of 87 marine caves had been explored so far and included to the database mentioned above.

Ilgarini Cave
Ph. M. Albukrek

## ARTIFICIAL CAVES

Artificial cavities and rock dwellings are widely available not only in the Cappadocia region, but in almost every part of Anatolia. All these structures excavated in different rocks, are hundreds of kilometers and over a period of thousands of years apart, but are mostly excavated for similar purposes and show an incredible variety, from dwellings to depots, from religious buildings to defense structures. There are regions with intense rock-dwelling concentration in different parts of Anatolia. Apart from Cappadocia, one of the most important places where such structures are seen is the region known as "Phrygian Highlands" in the provinces of Eskişehir - Afyon in northwest Anatolia.

In Central Anatolia there are numerous rock-cut structures carved into the nitritic soft limestone in Karaman Province. Especially the cliff settlements in Gödet Village contain countless dwellings on both walls of an 11 km long canyon. The soft limestone found in southeastern Anatolia, especially around Hasankeyf, Urfa and Gaziantep, has been excavated for centuries and many different structures have been built, from houses to churches. There are hundreds of dwellings dug into the Tigris River walls and the ancient citadel walls in Hasankeyf, and inside the cities and Euphrates River walls in Urfa and Gaziantep. On the other hand, in eastern Anatolia; hundreds of rupestrian settlements have been identified, surveyed and documented during long years of archaeological studies, especially in Ani and Ahlat. In northeast Anatolia, the cliff settlements and rock-cut churches research in the region stretching from Ardahan to Georgia, especially in the Kura River basin, has recently started.

Tilkiler Cave
Ph. A.E. Keskin

On the other hand, in terms of rock-cut structures, Cappadocia Region is very different from all these other regions mentioned above. The difference is that besides the sheer number of rock-cut churches or dwellings in this region, there is a troglodyte civilization in a very large region that lasts for hundreds, if not thousands, of years. Cappadocia's underground and rock-cut structures are both incredible in number and variety. Throughout history, there are numerous types of rock-cut structures ranging from structures used as residential, storage, barn to apieries and dovecotes. There are numerous defensive structures such as irrigation tunnels and cisterns such as hydric, churches, monasteries, tombs, religious and underground cities in the region, and a comprehensive database of all these structures exceeding thousands is not available.

## NATIONAL CAVING ORGANIZATION:

- Speleological Federation of Turkey (TMF) www.tumaf.org

## NUMBER OF SPELEOLOGISTS: ~560

## NUMBER OF SPELEOLOGICAL GROUPS AND ORGANIZATIONS: 19

## MAIN SPELEOLOGICAL PUBLICATIONS:

- "Delta" www.bumak.boun.edu.tr
- "Obruk" www.obruk.org
- "MAD Bülten" www.mad.org.tr

Balatini Cave
Ph. B. Langford

## BIOSPELOLOGY

The distribution and abundance of cave microorganisms in Turkey represents a similar composition with the karstic caves around the world. One of the first research focused on cave microflora has investigated 19 karstic caves located in different regions of Turkey. In the extent of this study, the distribution of Streptomyces genus in Actinobacteria phylum was examined in these caves. Some of these streptomyces isolates were selected to be evaluated in terms of their antimicrobial activities. In a study conducted to examine the microbial diversity in İnsuyu Cave (Burdur), the most common class was observed to be the Alphaproteobacteria (% 89.23 of the total bacteria). In another study examining the cave bacteria flora in Gilindire Cave (Mersin), the distribution was identified as Actinobacteria (39%), Proteobacteria (3%3), Firmicutes (17%) and Bacteriodetes (5.5%) in addition to uncultured organisms (5.5%).

Besides the microflora, macro-organisms like bats, fish, insects and spiders in cave environments were also examined by biological studies in Turkey. First known bio-speleology research is widely attributed to Dr. Abdullah Bey which refer to his study in Yarımburgaz Cave (İstanbul, Turkey) in 1865. On the other hand, the first study conducted with a systematic approach was conducted by the Spanish naturalist and insectologist Ignacio Bolivar on samples gathered by his colleague M. Martinez, who visited to Anatolia for his own studies. Among almost 100 different species of arthropods which were collected from the area that extends from İskenderun to Maraş and from the Taurus Mountains to the Binboğa Mountains, the species gathered from Yenicekale (Kahramanmaraş, Turkey) and Akbaş Caves (İskenderun, Turkey) are the very first macro-organisms sampled from cave environments in Anatolia. Primarily focused on cave crickets and arachnoids, there have been many arthropod studies conducted in various parts of Turkey since then.

In one of these researches, the individuals identified as Discoptila beroni (Insecta: Ensifera: Gryllidae) were observed larger in body sizes within the Yalan Dünya Cave (Antalya, the southern of Turkey) than the ones detected in the nearby area. Two new species identified in another study conducted in Artvin (the Black Sea region of northeast Turkey) in 2007. A study on cave microclimate and distribution of cave cricket species was conducted by Taylan and his team (2020). Aside from locusts, arachnoids, millipede, amphipoda, fishes, ostracoda and planktons were examined in various cave studies.

Bats composing of a large part of cave dwellers are studied all over the country. One of the most extensive studies on cave-dwelling bats in Turkey was conducted by Furman and Özgül in eastern Thrace in 1999 - 2000 and in western Thrace in 2001. From eight

Insuyu Cave
Ph. A.E. Keskin

underground sites in Eastern Thrace, 17,000 bat records representing eight species were covered, while there were approximately 76,000 bat records, representing 13 species from 32 underground sites covered from the western extension. Koyunbaba and Dupnisa Caves were reported to be the most important caves for bat dwelling, hibernaculum and nursery.

## LEGAL STATUS OF CAVES AND PROTECTİON RULES

Although there is no specific law for the protection of natural and artificial caves in Turkey, Law No. 2863 (Cultural and Natural Heritage Protection Law) also includes caves. The purpose of this Law is; to determine the definitions of the cultural and natural assets that need to be protected, to organize the operations and activities to be carried out, to take the necessary principles and implementation decisions in this regard. Apart from this work carried out by the relevant ministries, the Protection Board in each province convene once a month and take decisions on specific cultural and natural assets to be protected and inform the Ministry of Culture and Tourism about these decision. Natural and artificial caves in the national parks are under the authority of the Ministry of Agriculture and Forestry.

Based on the law mentioned above, the ownership of caves in Turkey basically belongs to the state and this also includes caves located on private lands. Individuals can rent a cave from the state for a certain purpose, such as opening it to tourism, but this activity must first be examined by the Protection Board in that province and a positive opinion should be given. Artificial caves found under the houses in some regions such as Cappadocia, Gaziantep and Urfa are also within the scope of Law No. 2863, and this creates serious conflicts and problems.

Altinbesik Cave
Ph. R. Straub

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